The American Journal of Surgery

VOLUME 97 MAY 1959 NUMBER FIVE

Fractures of the Shaft of the Tibia

A CLINICAL AND EXPERIMENTAL STUDY

R. W. JACKSON, M.D.* AND IAN MACNAB, F.R.C.S., *Toronto, Ontario, Canada*

From the Orthopaedic Service, Toronto General Hospital, Toronto, Ontario, Canada. This work was sponsored by grants from the Foster Foundation and the National Research Council of Canada.

FRACTURES of the shaft of the tibia are notoriously difficult to treat. A study of the patients treated at the Toronto General Hospital and Sunnybrook Military Hospital over a nine-year interval supports this view. Three hundred sixty-eight cases of simple and compound fractures were analysed; of these, only 16 per cent were united within three months and only 62 per cent were united by six months. Even after eighteen months, 2 per cent were still un-united and 2 per cent had required amputation. A review of the literature revealed that other centres had also recognized the difficulties inherent in the treatment of fractured tibias, and were facing the same problems.

In the hope that we would learn some means of improving these results, we undertook to investigate the various factors which might influence the rate of union of fractures of the tibia.

Influence of Blood Supply. Injection studies of the vascular network of the tibia (human cadavers and dogs) [12] revealed that there are three main sources of blood supply: the nutrient artery, the metaphyseal vessels and the periosteal vessels. The nutrient artery enters the bone at the junction of the upper and middle thirds and runs a long, oblique course through the cortex. It does not give off any branches during its intracortical course. Once the nutrient artery enters the medulla it traverses the medullary canal, giving off a dense, brush-like network of vessels that enter the cortex from its endosteal surface. (Fig. 1.) The nutrient vessels anastomose freely with the proximal and distal metaphyseal vessels, but do not anastomose at all (in resting bone) with the periosteal vessels.

The periosteal vessels are derived from the main vessels of the limb and run transversely to the long axis of the bone. These transverse branches anastomose freely with each other and with arteries supplying the surrounding muscles. We were unable, by injection techniques, to demonstrate any vessels derived from the periosteum entering the cortex, and the relatively insignificant role of the periosteal vessels in resting bone is further suggested by the fact that nine-tenths of the cortex died following blocking of the endosteal circulation.

Although the periosteal vessels may be of little significance in the nutrition of the resting adult tibia, they are of vital importance following fracture. The nutrient vessels run longitudinally and when the bone is broken experimentally with complete interruption of the endosteal circulation, the distal fragment becomes avascular. The periosteal blood supply, however, is intact on both sides of the fracture line, since the periosteal vessels run transversely to the long axis of the bone. (Fig. 2.) Following interruption of the endosteal circulation to the distal fragment, the distal endosteal callus forms at some distance from the fracture site and takes a long time to unite with the endosteal callus of the proximal fragment, whereas periosteal callus forms rapidly and quickly seals the fracture gap. These periosteal vessels perform another important function by assisting in the revascular-

* Orthopaedic Research Fellow, Banting Institute, University of Toronto.

FIG. 1. An injected human tibia, prepared by Spalteholz method. Photograph taken with specimen lying in methyl salicylate. The specimen shows the obliquely running nutrient artery breaking up into its two main branches. From these branches a dense, brush-like network of vessels is formed in the medulla of the bone. From this network, arterioles enter the endosteal surface of the cortex. Some of these arterioles can be seen in this photograph.

ization of the distal fragment. In so doing they help to restore the distal endosteal circulation and thereby assist in the production of endosteal callus distal to the fracture.

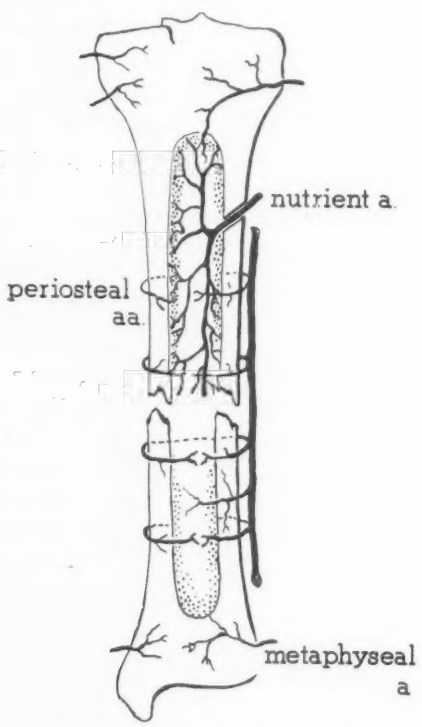

FIG. 2. Diagram shows that although the endosteal system is interrupted by a fracture, the periosteal blood supply remains intact on both sides of the fracture line. This is because of the peculiar anatomical configuration of the periosteal vessels which run transversely to the long axis of the bone.

If the periosteum is destroyed, there is difficulty in restoring the endosteal circulation of the distal fragment, distal endosteal callus forms at a considerable distance from the fracture site, there is no periosteal seal to close the gap, and ultimately fibroblasts derived from the injured soft tissues spread between the bone ends and produce a fibrous union.

The importance of the periosteal seal can be demonstrated by a very simple experiment. If a portion of the fibula is resected (2 cm. in a dog), the gap produced is filled by surrounding tissues, and no attempt is made to bridge the gap with bone. However, if the defect in the fibula is bridged by a polyethylene tube filled with blood, new bone grows down the tubing and reconstitutes the fibula. If the experiment is repeated using a perforated polyethylene tube, fibroblasts spread in through the perforations and the defect is bridged by fibrous tissue only.

It is suggested, therefore, that in fractures, the periosteum acts in an analogous manner to the polyethylene tubing—as a barrier against infiltration of the fracture site by fibrous tissue.

Influence of Soft Tissue Injury. The experiments on the blood supply of the tibia suggested that the damage sustained by the periosteum (stripping and interference with blood supply) at the time of injury played a vital role in determining the rate of union of fractures. It was believed that the degree of initial displacement of the bony fragments

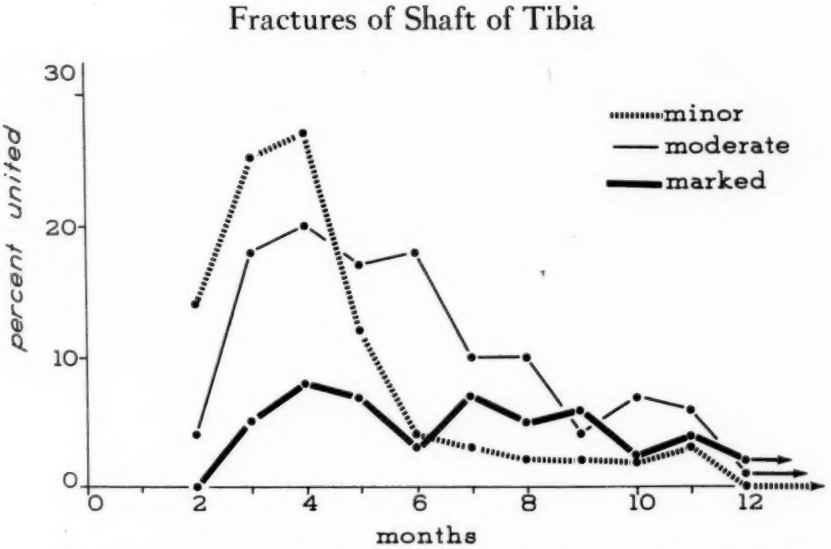

FIG. 3. Rate of union. All cases correlated with initial displacement. The total number of cases is divided into three categories of initial displacement, and the percentage of cases successfully uniting during each month is indicated.

might give some indication of the periosteal damage sustained. To study this, 214 cases of tibial fractures which united without secondary procedures were analyzed. The only means available to assess the degree of initial deformity was the displacement revealed in the first x-ray films taken. The degree of initial displacement was arbitrarily classified as minimal, moderate and marked.* The time taken for the fracture to unite was correlated with these various classifications of initial displacement. It was noted that when the initial displacement of the bone fragments was marked, there was no instance of union under three months, whereas with moderate displacement, union occasionally occurred in two months and with minimal displacement one case united in six weeks. The majority of fractures with minimal displacement were united in four months, whereas with marked displacement the majority were still un-united at six months. The effect of the initial displacement on the rate of union is convincingly demonstrated by an analysis of the percentage of each group uniting in the third, fourth and sixth months. (Table I.) Note in those cases showing marked initial displacement, 89 per cent were still un-united six months after injury.

* Minimal displacement was considered to be angulation alone or fragmental displacement of up to 25 per cent of the width of the shaft. Moderate displacement consisted of up to 75 per cent of the width of the shaft with gross angulation. Marked displacement was considered to be 75 per cent or more of the shaft width, plus marked rotation of the distal fragment and/or gross comminution.

Whatever mode of treatment was employed it was consistently demonstrated that the greater the initial displacement, the longer it was required for union to occur. (Figs. 3 and 4.) Furthermore, 90 per cent of the sixty cases in our total series, which subsequently required bone-grafting procedures, showed moderate to marked initial displacement.

These facts tend to substantiate the view previously expressed, that the extent of the damage sustained by the periosteum at the time of the injury is of greatest importance in determining the rate of union and the incidence of non-union.

Influence of Compounding. To study whether compounding without subsequent infection had any influence on the rate of fracture healing, we tried to exclude all possible known variants, that is, the anatomical site, the displacement, the method of treatment, etc. To do this, comparable groups were studied. The result of this study showed that compounding, *per se*, does slow healing. It was noted that

TABLE I
INITIAL DISPLACEMENT AND PER CENT UNITED

Months	Displacement		
	Minimal (%)	Moderate (%)	Marked (%)
3	25	15	3
4	48	31	5
6	60	53	11

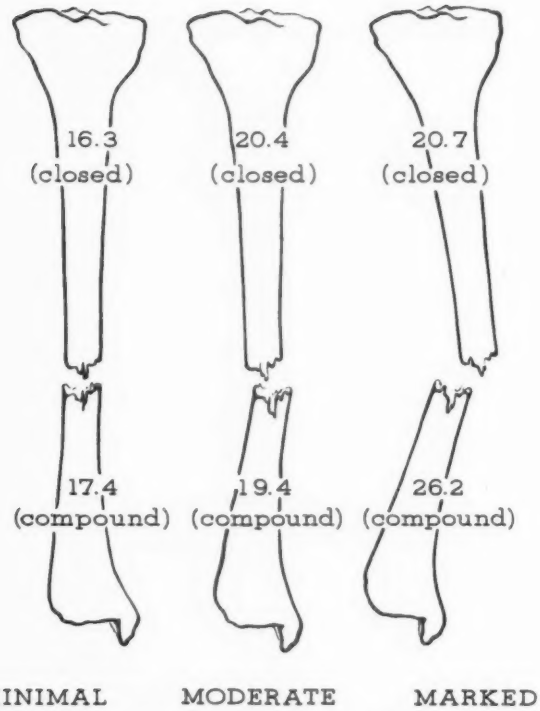

FIG. 4. The times of union in weeks of closed and compound fractures treated by all methods, in relation to the amount of initial displacement as shown by radiographs.

86 per cent of closed fractures showing primary union were united in six months or less, whereas only 66 per cent of compound fractures were united in the same period of time. However, it was found that with minimal displacement, compounding did not appreciably alter the time of union. This seems reasonable when one considers that there is probably very little soft tissue damage when a compound fracture is not associated with moderate to marked displacement of the bony fragments. With moderately to markedly displaced fractures, however, compounding produces a significant difference in the time of healing. Transverse, moderately or markedly displaced fractures treated by plaster united in an average of 17.2 weeks when initially closed, and in 26.2 weeks when originally compounded. Similarly, moderately to markedly displaced comminuted fractures that were closed united in 21.1 weeks, whereas moderately to markedly displaced fractures that were comminuted and compound united in an average of twenty-eight weeks. Probably the delayed union seen in compound fractures, not complicated by osteomyelitis, is a further example of the effect of soft tissue injury in determining the rate of union.

TABLE II
CALLUS FORMATION

Age Group	Minimal (%)	Moderate (%)	Profuse (%)
16–30	43	51	6
30–60	56	39	5
60 plus	64	32	4

Influence of Age. The cases were divided into four age groups: zero to sixteen, sixteen to thirty, thirty to sixty and sixty plus. Under the age of sixteen, union was found to be rapid, a fact which has been corroborated by many other reviews. In the other three age groups, although there is more callus formation in the younger ages, there is no significant difference in the time of union. (Table II.)

Influence of Site. It is commonly accepted that fractures involving the lower third of the tibia are slow in uniting. It has been suggested [*21*] that the reason for delayed union at this site lies in the poor vascularity of this part of the bone. Our injection studies did not corroborate this fact, as the vascular supply to the lower third of the tibia was found to be no less than elsewhere in the shaft. Moreover, following fractures of the middle third just distal to the entrance of the nutrient artery, a greater portion of the shaft is rendered avascular than in fractures of the lower third where the fracture line lies nearer the distal metaphyseal vessels and revascularization of the distal fragment is easier. (Fig. 5.)

It would appear, therefore, that the apparent indolence of fractures of the lower third of the tibia is dependent on other factors than vascularity.

In order to investigate this further, all cases with complications were excluded and seventy-two closed fractures of the tibia which successfully united on conservative treatment were analyzed. In this group it was found that the average time of union was between 17.1 and 17.7 weeks, regardless of site. (Fig. 6.)

The innocuous character of the lower third of the tibia is further emphasized by the fact that in this series bone-grafting procedures were more frequently performed for fractures in the middle third than in the lower third. (Table III.)

In the group of sixty-seven cases referred to

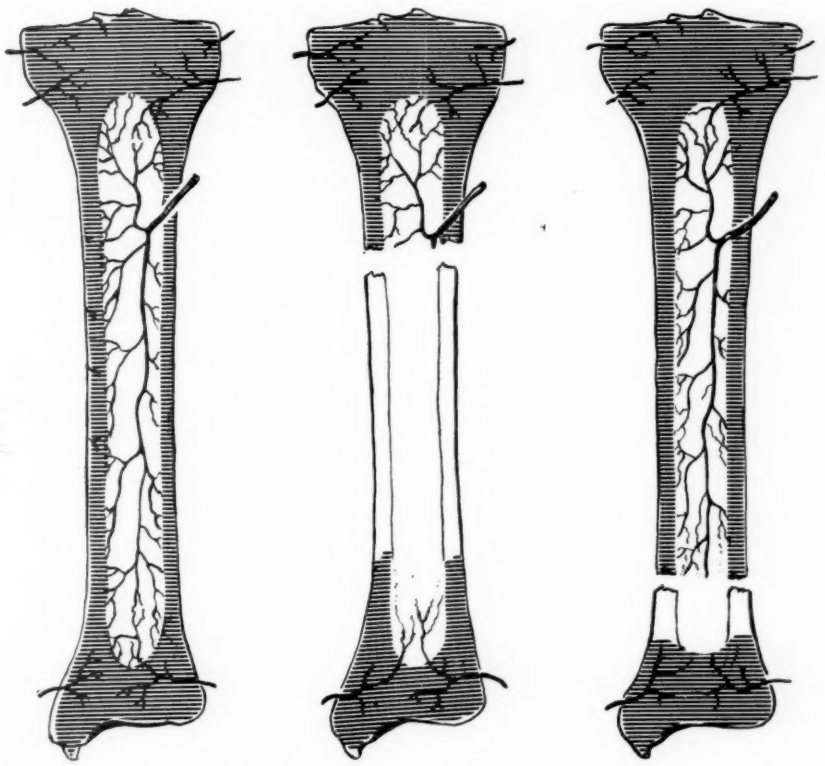

FIG. 5. Diagram shows that when a tibia is fractured near the nutrient artery, i.e., in the middle third, a greater portion of the tibial shaft is rendered relatively avascular at the time of the accident than when the fracture occurs in the lower third of the tibia. It would appear logical therefore that revascularisation of the distal fragment is easier in fractures of the lower third than in fractures of the middle third. We believed there was experimental evidence to show that the relatively avascular cortex acted indeed as a stimulus to greater callus production. Clinically, callus production is always more profuse in fractures of the upper third than in the lower third. Experimentally, however, a great amount of callus can be produced in the lower third if the endosteum is reamed out and the medullary canal filled with wax, producing death of the cortex.

this centre as problems in management, it was further found that no one site was particularly troublesome.

It can be reasonably concluded, therefore, that the site of fracture has no influence on the rate of healing, and disrepute of fractures of the lower third is due to other factors. The lower third of the tibia is not surrounded by muscles, and severe displacement of the fragments occurs with greater frequency here than at other sites. Moreover, the periosteum, divested of supporting muscle, is likely to be stripped and shredded by such displacements. This was demonstrated by dissection of various fractures produced experimentally in amputated limbs. It is suggested that the greater incidence of associated soft tissue injury found in fractures of the lower third of the tibia accounts for the tardy healing, and that the site by itself is of little importance.

TABLE III
PERCENTAGE OF CASES REQUIRING GRAFTS AT EACH SITE

Site of Fracture	Per cent
Upper third	17
Middle third	24
Junction of mid- and lower third	15
Lower third	15
Double fractures	31

Influence of Type of Fracture. When assessing whether the type of fracture sustained played any part in influencing the rate of union, it was again necessary to study a group of cases in which variables such as compounding, treatment and secondary procedures were excluded. The same group of seventy-two fractures successfully treated by conservative means was used. Four fracture types were considered: transverse, oblique, spiral and comminuted. (Minor degrees of comminution were allowed in the first three types.) It was found

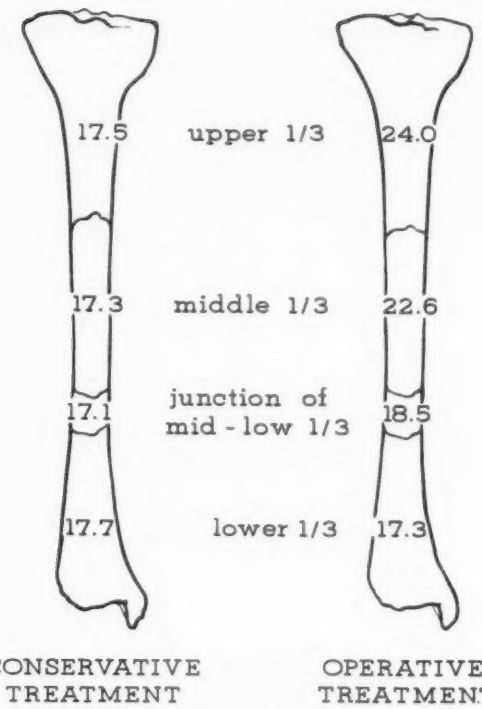

FIG. 6. A study of all closed (simple) fractures (excluding all those developing complications) showing the average time of union (in weeks) of fractures occurring at various sites along the shaft.

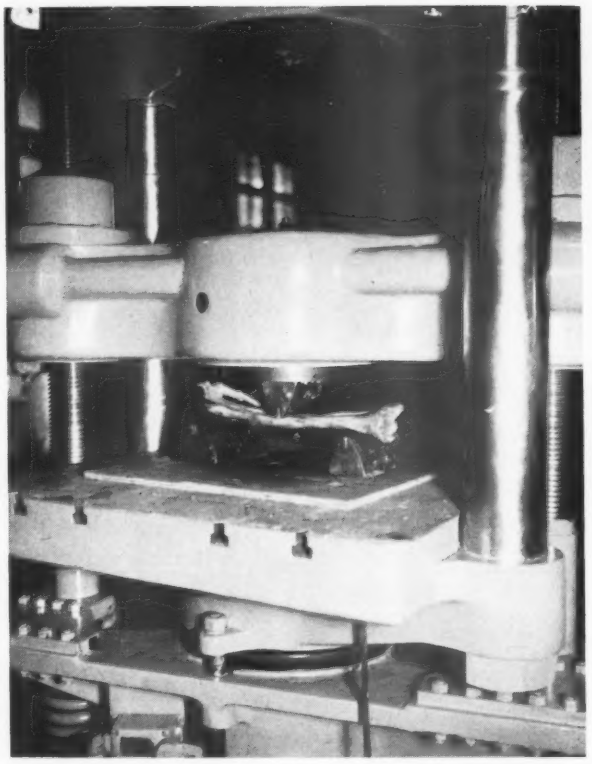

FIG. 7. Dissected specimen of freshly amputated limb being tested for bone strength in one of the machines at the Structural Testing Laboratories, Faculty of Engineering, University of Toronto. This tibia fractured when the steadily increasing load at its midpoint reached 850 pounds.

that in the group of seventy-two cases, transverse fractures united in an average time of thirteen weeks, oblique fractures in seventeen weeks, and spiral and comminuted fractures in twenty weeks. These findings were obviously contrary to the commonly expressed view that transverse fractures are slow to unite. Consequently, experiments were conducted to determine the mechanism of production of these various fracture patterns.

Working in conjunction with the Structural Testing Laboratories of the Faculty of Engineering, University of Toronto, freshly amputated limbs and dried anatomical specimens were subjected to pure forces of measurable magnitude [7]. (Fig. 7.) The forces used in the study were: (1) force applied at right angles to the long axis of the bone, (2) vertical compression through the long axis of the bone, (3) torsion and (4) impact.

It was found that a transverse fracture was the basic stress defect to occur in a tubular structure such as the tibia. Using a steadily increasing load applied at right angles to the long axis, a transverse stress defect occurred at 750 to 850 pounds of pressure. (Fig. 8.) With the addition of momentum to the force, i.e.,

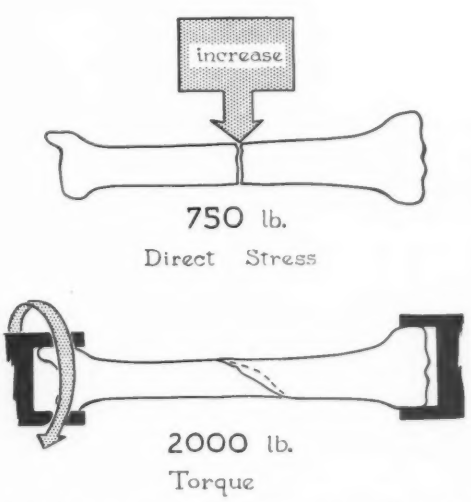

FIG. 8. When a steadily increasing force is applied at right angles to the long axis of a tibia, a transverse fracture results. If the load is applied in a spiral fashion, three times the force is necessary to fracture the bone and, as expected, the fracture is spiral in nature.

impact, a transverse fracture (Fig. 9) could be produced by 72 foot pounds of force. As the force of the impact increased, comminution of the bone occurred (at approximately 120 foot pounds of force). When pure torsion was applied to the bones, the force necessary to produce a fracture was almost triple that necessary with a slowly increasing load at right angles. Under torsion, a consistent 2,000 to 2,400 pounds per square inch of pressure was necessary to produce a fracture defect which, as expected, was spiral in nature. Pure vertical compression failed to crack the cortical shaft in any case. The medial and lateral condyles would shatter when the load reached 2,500 to 3,000 pounds, and progressive mushing of the cancellous upper and lower portions of the bone occurred if the force was continued.

It is realized that the tibia is rarely subjected to pure forces as just described. In most cases there is a combination of a vertical compression force (the person's weight), and either torsion or a right angle force associated with varying degrees of impact (in addition, some of the injuring force would be dissipated throughout the adjacent joints and ligaments). If, however, a force of 2,000 pounds is expended on the tibia in such a fashion that a transverse fracture would result, only 750 pounds is required to break the bone, and the remaining force would be absorbed by the surrounding soft tissues after the bone breaks. The soft tissue damage, therefore, would be much more severe in this type of fracture than if the same amount of force was applied in a spiral fashion, as the majority of the force would be expended in producing the fracture and relatively little would remain to act further on the soft tissues. With the addition of the impact an even smaller proportion of the 2,000 pounds of force would be expended in shattering the bone, and the remainder would be dissipated in the soft tissues. It would appear, therefore, that transverse fractures are likely to be associated with more damage to the soft tissues than spiral or oblique fractures. In this regard, it is interesting to note that there were no instances of spiral fractures subsequently requiring bone grafting.

It is difficult to know how much significance one can place on such experiments. However, it is certainly probable that the ill repute of transverse fractures is not due to the anatomy of the fracture line but rather to the commonly associated soft tissue injury.

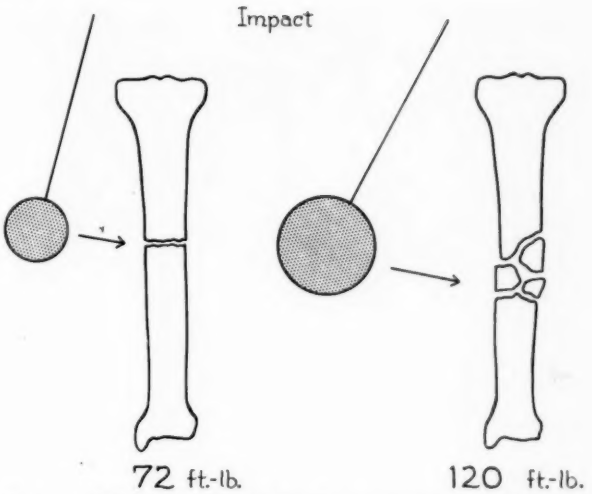

FIG. 9. With the addition of momentum, much less force is required to produce a transverse fracture, and comminution results as the force is increased.

Conclusions. In this study of normal or uncomplicated fracture healing we have assessed aspects inherent in the fracture that might influence the rate of union. It would appear that the age of the patient and the site of the fracture are of no significance, but associated soft tissue damage as indicated by the degree of initial displacement and compounding is of great importance and has a profound effect on the rate of healing of comparable cases. A knowledge of the significance of these variables out of the control of the surgeon facilitates the comparison of various methods of treatment.

ANALYSIS OF TREATMENT

For the purpose of assessing the various methods of treatment, 301 fractures initially treated at the Toronto General Hospital and Sunnybrook Military Hospital were reviewed. A study was also made of sixty-seven cases referred from other centres as problems in management, and from this latter group of cases further information was obtained on common complications of treatment.

Simple (Closed) Fractures. There were 188 cases of simple fractures of the tibia, of which ninety-seven were treated by closed methods and ninety-one by open reduction and internal metal fixation. (Table IV.)

An analysis was made to compare the rate of union and incidence of complication in comparable fractures whether treated by closed or open reduction. In all instances, with one exception (markedly displaced spiral oblique fractures), union was more rapidly

FIG. 10. Non-union following plate fixation. Picture shows result five months after transverse fracture was adequately plated. Note that the plate securely holds the fragments in perfect alignment and that resorption of bone ends has occurred producing distraction at the fracture site. Note also the complete lack of callus formation.

achieved when closed reduction was employed and the incidence of complications was less. The more extensive the operative procedure, the slower the rate of union and the greater the incidence of complication. This fact was convincingly demonstrated by a study of fractures treated by metal plates. Plates were employed in fourteen instances, and in eight (57 per cent) further operative treatment was required. In all cases showing marked initial displacement and treated by plates, bone grafting was required at some later date. This again emphasizes the adverse effect of soft tissue injury (whether produced by the accident or by the surgeon) on determining the speed of union. (Fig. 10.)

The findings of our analysis support the largely forgotten dictum that open reduction should be reserved for those cases in which closed manipulation fails to obtain or maintain the reduction.

TABLE IV
CLOSED FRACTURES

Type of Fracture	Conservative Treatment												Operative Treatment												Totals			
	Plaster of Paris			Pins and Plaster of Paris			Traction			Screw			Plate			Intramedullary Nail			Primary Grafting			Cortical Wiring			Conservative Treatment		Operative Treatment	
	a*	b†	c‡	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	c	a	c
Minimal displacement:																												
Transverse spiral oblique	43	15	4.7%	..	....	.....	..	....	.....	23	16.5	13%	..	....	.....	..	....	.....	..	....	.....	1	34	0	43	4.7%	24	12.5%
Comminuted	10	17.5	10%	..	....	.....	1	14.0	0	4	18.5	0	2	18	50%	..	....	.....	..	....	.....	..	....	.....	11	9.0%	6	16.6%
Moderate displacement:																												
Transverse spiral oblique	15	17.8	26.6%	4	20.5	0	3	30	0	20	16.5	5%	3	24	33%	..	....	.....	2	19	0	1	22	0	22	18.1%	26	7.6%
Comminuted	10	21.7	20%	2	16	50%	3	12	33%	7	29.2	28.5%	6	23	50%	4	26	25%	3	21	30	1	28	0	15	26.6%	21	28.5%
Marked displacement:																												
Transverse spiral oblique	2	15	0	..	....	.....	..	....	0	4	21	0	1	..	100%	..	....	.....	1	22	0	..	....	.....	2	0	6	16.6%
Comminuted	2	18	0	..	....	.....	2	22	50%	2	24	50%	2	..	100%	2	32	50%	1	20	0	1	..	100%	4	25%	8	62.5%
Totals	82	....	10.9%	6	....	16.6%	9	....	22.2%	60	....	11.6%	14	....	57.1%	6	..	33.3%	7	....	0%	4	..	25%	..	.....	..	.....

* a = Number of cases.
† b = Union in weeks (average of cases) without complications.
‡ c = Percentage of complications.

TABLE V
COMPOUND FRACTURES

Type of Fracture	Conservative Treatment												Operative Treatment																Totals			
	Plaster of Paris			Pins and Plaster of Paris			Traction			Roger-Anderson Fixation			Screw			Plate			Intramedullary Nail			Primary Grafting			Cortical Wiring			Conservative Treatment			Operative Treatment		
	a*	b†	c‡	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Minimal displacement:																																	
Transverse spiral oblique	8	14.6	12.5%	..	....	.....	..	....	.....	..	....	.....	6	20.8	16.6%	..	....	.....	..	....	.....	..	....	.....	..	....	.....	..	....	.....	8	12.5%	6	16.6%
Comminuted	0	....	.....	..	....	.....	..	....	.....	..	....	.....	..	....	.....	..	....	.....	..	....	.....	..	....	.....	..	....	.....	..	....	.....	..	.....	..	.....
Moderate displacement:																																	
Transverse spiral oblique	12	24.1	41.6%	3	19.0	33.3%	..	....	.....	..	....	.....	2	22	0	1	34	0	1	..	100%	1	16	0	..	....	.....	15	40%	5	20%
Comminuted	9	28	77.7%	1	24	0	3	20	0	..	....	.....	7	22	28.5%	6	30	66.6%	..	....	.....	2	23	0	2	..	100%	13	53.8%	17	47%
Marked displacement:																																	
Transverse spiral oblique	5	31	40%	..	....	.....	..	....	.....	1	40	0	2	18	50%	1	30	0	..	....	.....	..	....	.....	..	....	.....	6	33.3%	3	33.3%
Comminuted	9	28.8	44.4%	2	....	100%	6	26	66.6%	5	30	80%	3	14	33.3%	4	22.5	0	2	..	100%	2	24	50%	1	32	0	22	63.6%	12	33.3%
Totals	43	....	44.0%	6	....	50%	9	..	44.4%	6	..	66.6%	20	....	25%	12	....	33.3%	3	..	100%	5	..	20%	3	..	66.6%	..	.....	..	.....		

* a = Number of cases.
† b = Union in weeks (average of cases) without complications.
‡ c = Percentage of complications.

Compound (Open) Fractures. There were 107 cases of compound fractures available for review; sixty-four cases were treated conservatively and forty-three were treated by internal fixation. (Table v.) The difficulties inherent in the management of this particular type of tibial fracture are well exemplified by the fact that in thirteen (12.3 per cent) osteomyelitis developed, and of those who escaped infection, twenty-two (23.4 per cent) required bone grafts. Of the thirteen cases in which osteomyelitis developed, twelve were still un-united in six months, and eight had bone-grafting procedures performed at subsequent dates.

Even if fractures in which osteomyelitis developed were excluded, only 66 per cent of compound fractures were united within six months, whereas in the same period of time 86 per cent of closed fractures were united.

It is interesting to note that with minor compounding and minimal displacement, the rate of union was similar to a comparable group of minimally displaced closed fractures. The commonly observed delayed union in other cases can be related to the gross damage sustained by the periosteum and soft tissues by the initial displacement of the bone fragments.

The periosteum in compound fractures is commonly shredded at the time of injury and may be further damaged by the operative débridement. Bare bone is frequently opposed to bare bone. In the process of healing there is no opportunity to form a periosteal seal, and it is simple for fibrous tissue to infiltrate between the bone ends. The best means of preventing this is to ensure close apposition of the bony fragments. In this regard, it is interesting to note that if apposition was securely held by a minimal operative procedure, e.g., screw nails, the compound fractures united more quickly. (Table vi.) The use of such minimal internal fixation did not increase the incidence of osteomyelitis. However, if the use of the internal fixation involved extensive dissection, as in the application of plates, the results were disastrous. Plates were employed in eleven patients with compound fractures: osteomyelitis developed in two, four showed delayed union and two went on to frank non-union. In only four cases was the result as satisfactory as could be expected by other methods of treatment.

Of the thirty cases of compound fractures

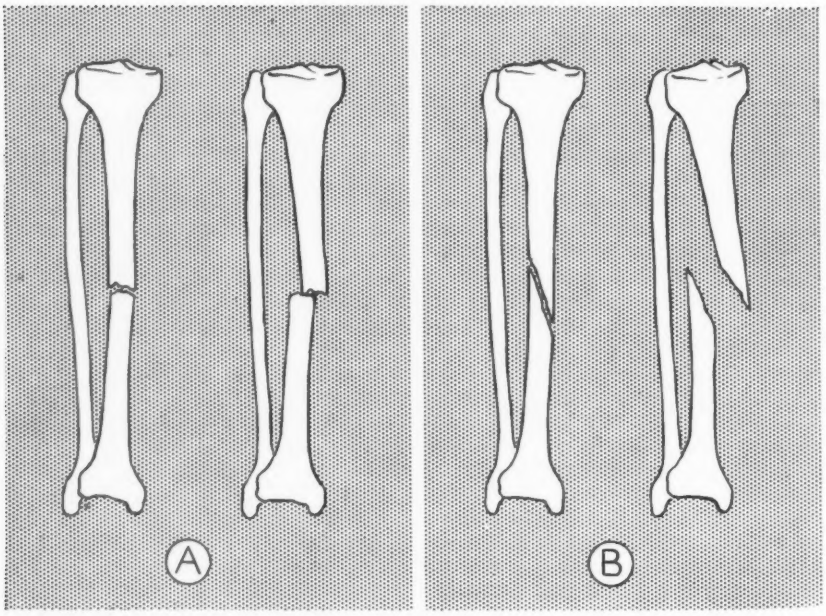

FIG. 11. In cases with intact fibulas, shortening is prevented. Therefore, with an oblique fracture, movement or displacement causes distraction, whereas with a transverse fracture, contact between the fragments is always maintained.

referred to the Toronto General Hospital for problems of management, thirteen were treated initially by plates. Of these, three were originally transverse fractures which required bone grafts at sixteen, eighteen and twenty-seven months, respectively, for non-union. The remaining ten were initially comminuted fractures and osteomyelitis developed in eight.

In summary, it can be said that in the treatment of compound fractures, internal fixation with minimal operative trauma may speed union, but if the use of internal fixation involves extensive dissection, as in the use of plates, union is delayed and there is a marked increase in the number of complications.

TABLE VI
AVERAGE TIME OF UNION

Category	Conservative Treatment (wk.)	Minimal Operative Treatment (wk.)
Moderately displaced:		
Spiral oblique	24	22
Comminuted	28	22
Markedly displaced:		
Spiral oblique	31	18
Comminuted	28	14

SPECIAL PROBLEMS IN TREATMENT

Double fractures and fractures of the tibia with an intact fibula were believed to constitute special problems in management and were considered separately.

Intact Fibula. The presence of an intact fibula is of importance in the treatment of a fractured tibia only in those cases in which the fracture is oblique in nature. With a transverse fracture, lateral and rotary movements may occur without loss of apposition but with oblique fractures, lateral angulation causes distraction at the fracture site. (Fig. 11.) This type of fracture, then, is better treated by screw fixation. There was less than 10 per cent incidence of delayed union in the forty-five cases of intact fibulas.

Double Fractures. The treatment of double fractures depends on the site and the degree of displacement. (Fig. 12.) If the nutrient artery enters the central fragment, there is no problem. If the upper fracture is distal to the entrance of the nutrient artery, the degree of displacement is important. When the displacement is minimal, the periosteal blood supply is usually intact and will restore the endosteal circulation in the free central fragment. The six cases in this category all united on conservative treatment. There were eight cases with more extensive soft tissue damage,

six of which required bone grafting of the lower fracture. It is suggested, therefore, if closed reduction cannot be obtained, that these cases of severe soft tissue damage be treated by intramedullary nailing to avoid further damage to the periosteum, and the lower fracture site be reinforced by cancellous onlay bone grafts.

TREATMENT OF THE MAJOR COMPLICATIONS

The major complications considered in this review were osteomyelitis, non-union and delayed union. As expected, there was a higher incidence of complications in the group of compound fractures. Complications developed in 53 per cent of the compound fractures treated conservatively and 45 per cent of those treated operatively. The complication rate also rises when closed fractures are treated operatively. Closed fractures treated conservatively showed an 11 per cent complication rate, rising to 24 per cent with operative intervention.

Osteomyelitis. There were fifteen examples of osteomyelitis in the series, giving an over-all incidence of 5.1 per cent. Of these, only two occurred following open reduction of closed fractures (2.1 per cent) and both these cases were before 1951. The remaining thirteen cases occurred in compound fractures (12.3 per cent). Fourteen cases were still un-united at six months, and amputation was performed in four cases.

To study the effect of sepsis on fracture healing, experiments on bridging a fibular defect in dogs with a polyethylene tube were repeated. In these experiments the tubing was filled with autogenous pus instead of blood.

Serial x-ray films were then taken, which at two to three weeks showed a marked periosteal reaction at either end of the tubing containing pus. This reaction gradually subsided in eight to ten weeks and absorption of the bone ends was seen to occur. On the control side, new bone would gradually fill the gap and reconstitute the fibula. Frank non-union resulted on the septic side. (Fig. 13.)

Experiments were also performed to assess the effect of cortical and cancellous bone chips in the presence of infection. Bone fragments were placed inside the polyethylene tubing with the pus on one side and blood on the control side. Absorption of the bone fragments occurred more rapidly on the septic side. Cancellous bone chips seemed more resistant to pus than cortical chips and persisted on an average of two to four weeks longer than the cortical chips.

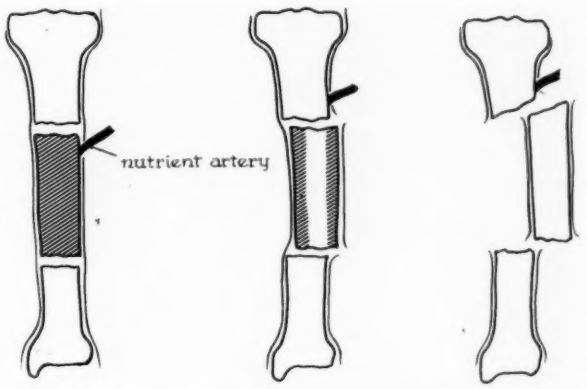

FIG. 12. Types of double fractures (see text). *Left*, nutrient artery entering free central fragment. *Middle*, upper fracture below entrance of nutrient artery. Periosteal blood supply intact. *Right*, fracture below entrance of nutrient artery and periosteal blood supply destroyed.

These experimental findings are in accord with clinical experience. The periosteum appears to be relatively resistant to infection and is easily stimulated to lay down new bone in the presence of sepsis. This is evidenced by the exuberant callus formation seen when infected fractures successfully unite and also in the periosteal hypertrophy seen in haematogenous osteomyelitis.

The experiments also show that cortical bone is very susceptible to infection and is readily destroyed. Osteomyelitis going on to non-union was seen most commonly in comminuted, markedly displaced compound fractures. In these cases the periosteum was probably severely stripped at the time of the injury and was further destroyed during the débridement of the wound. When infection supervenes, the denuded bone ends are destroyed and bone-to-bone contact is lost. Therefore, when the wounds of compound fractures are débrided, great care should be taken to protect the periosteum; it should not be excised unless grossly contaminated and incapable of being chemically or mechanically cleansed.

Although the presence of osteomyelitis has been called disastrous, union can still occur. In this series, four cases united spontaneously and seven others united following bone-grafting procedures. One of these successful bone grafts was a sliding cortical graft and the other six were cancellous onlay slabs. Cancellous bone grafts would appear to assure more success in

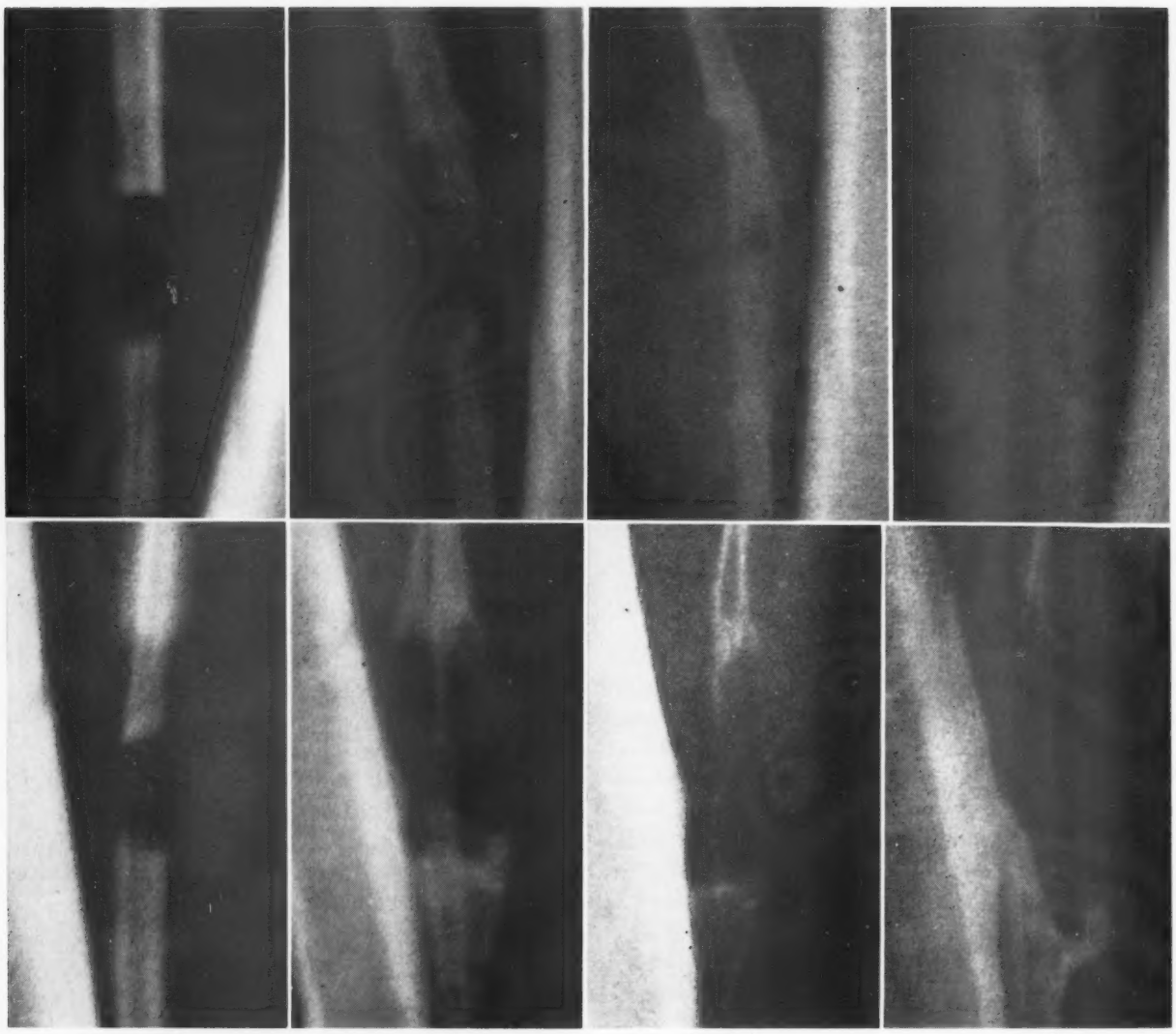

FIG. 13. Eight millimeter segment of fibula resected bilaterally in a dog and the gaps bridged with polyethylene tubing. *Upper row*, right leg. Tubing filled with blood at operation. Endosteal new bone formation seen at five weeks and gap bridged by solid bone at twenty-two weeks. *Lower row*, left leg. Tubing filled with homogeneous pus (Staphylococcus aureus). Marked periosteal reaction and new bone formation at five weeks, with subsequent resorption of periosteal and endosteal new bone and development of osteomyelitis by twenty-two weeks. Note also periosteal reaction on adjacent tibia.

the presence of latent infection than cortical grafts.

Delayed and Non-union. In this analysis, all patients having bone-grafting procedures performed after the initial four weeks following injury were considered as cases showing "delayed union." Undoubtedly this group contains some cases grafted before six months which would have united if left alone, and they should not be considered as cases of delayed union. Of the 301 cases treated at this centre, however, a total of sixty (20 per cent) had bone-grafting procedures. The most startling fact which arose from this study was the fairly consistent time of union following grafting—an average of nineteen to twenty weeks—no matter at what stage the bone-grafting procedure was performed. Thirty-one of the cases were grafted before six months had elapsed since injury and these united in an average of 19.4 weeks. The other twenty-nine cases were grafted after six months and these united in an average of 19.8 weeks after operation.

As mentioned before, the largest number of grafts were performed on fractures of the middle third (24 per cent), and not the junction

or the lower third as previously believed. Fifty fractures were initially transverse or comminuted in type and ten were originally oblique. Ninety per cent of the sixty bone-grafting procedures performed were successful. The six failures were evenly spread among cortical grafts and cancellous grafts, and failure was due to refracture or infection in each case.

Optimal Time for Bone Grafting. Controversy has existed for some time as to when bone-grafting procedures should be performed if delayed union is suspected. For our purposes we arbitrarily selected six months as the time after which delayed union could be said to occur. In order to study this question, the 214 cases which went on to successful primary union were analysed, and it was found that by six months only 59.5 per cent had successfully united. Therefore, 40.5 per cent of cases going on to primary union also showed delayed union. By six to ten months, however, there was a further union rate of 13 per cent of the total number, i.e., one-third of those showing delayed union. Considering the fact that only 16 per cent unite by three months, it was believed that early grafting, if performed at three to six months, would undoubtedly be unnecessary in most cases and increase the hazards of treatment. Therefore, it was reasoned that the primary form of treatment should be continued for six months before grafting is considered unless the graft is necessary to fill a gap, to correct distraction or for social or economic reasons. After a six-month interval has elapsed following fracture, we can expect that one-third of the cases still un-united will unite by themselves, if left alone, in approximately the same time required for union if a graft is inserted, i.e., four months. The other two-thirds will be benefited by grafting. At six months then, if any definitive indication exists that union might take place in the following four months, the decision for grafting could be postponed for a further period. If no indication of union exists, grafting should be performed at this time. It has also been shown that bone grafts inserted after six months unite as rapidly as those inserted before six months, so the argument that grafts performed earlier unite more quickly is not a valid one. Bone grafting should be regarded as an aid to union from six to ten months and as a cure for non-union, once established.

Primary Grafting. An interesting group of cases were thirteen in which bone-grafting procedures were performed as a primary method of treatment during the first four weeks following injury. All of these procedures were performed on patients with moderate or severe injuries, as judged by the presence of marked displacement, comminution and compounding, in which it was impossible to obtain a satisfactory reduction by conservative means. Eleven of the thirteen fractures (85 per cent) united in six months or less, whereas with all other methods of treatment only 62 per cent united in the same length of time. One disaster occurred—in one case of compound fracture, a sliding cortical graft was inserted; osteomyelitis developed and resulted in amputation two years later. This small series would indicate that primary grafting is an excellent form of treatment, and perhaps if any operative intervention is deemed necessary in the treatment of a fracture, the internal metal fixation should be reinforced by cancellous onlay bone slabs.

COMMENTS

It is believed that this study has demonstrated the importance of an intact periosteum in tibial fractures. There can be no doubt that the severity of the associated soft tissue injury markedly influences the rate of union, as shown by the close correlation between the degree of initial displacement of the fracture fragments and the time taken for union to occur, and also by the tardiness of union in non-infected compound fractures with severe soft tissue injury. Similar findings were reported by Ellis [4]. The experiments conducted demonstrated the indispensable role of the periosteum, and suggested that one important function was to form a barrier against infiltration of the fracture site by fibrous tissue. It might almost be said that in the treatment of a fracture the most important factor is consideration of the periosteum.

Two other points were repeatedly demonstrated: the efficacy of bone grafting and the hazards of extensive operative procedures.

Bearing these points in mind it is suggested that closed reduction is the treatment of choice for closed fractures. In this series a surprisingly high percentage of simple fractures were treated by internal fixation (52 per cent). This might be due to the fact that, in many cases, the initial attempt at closed reduction was

frequently performed in a perfunctory manner in an operating room set up for open procedures. If closed reduction is to be attempted it should be well done, and indeed, requires more skill than an open reduction.

There is one exception to the general rule of closed reduction of closed fractures. Our results confirm the findings of White [*24*] that moderately to markedly displaced spiral oblique fractures are more satisfactorily treated by screw fixation.

In those cases in which an adequate attempt at closed reduction has failed to obtain or maintain reduction, open fixation may be indicated. Here it must be remembered that the major indication for operation is to prevent significant deformity. The definition of "significant" deformity, however, requires further research. The decision to perform an open reduction should be made within fourteen days as by this time the normal processes of fracture healing are well established, and it is believed that operative intervention after fourteen days has a retarding influence on union.

If operative treatment is necessary it should be performed as soon as possible, and the surgeon should minimize the amount of soft tissue trauma needed to obtain apposition of the bone fragments. Extensive operating at any time should be avoided. As mentioned before, screw fixation affords a minimal amount of soft tissue trauma and should be used whenever possible. Lottes intramedullary nails are useful in the treatment of unstable transverse fractures. Whenever possible they should be inserted using the blind technique to avoid damage to the periosteum. In this series the use of metal plates was associated with an alarmingly high incidence of complication. Cortical wiring is an inefficient method of fixation, usually involving extensive exposure, and therefore should also be avoided. The excellent results obtained from primary grafting suggest that if extensive exposure of the fracture site is necessary, the internal fixation should be reinforced by onlay cancellous grafts. The indications for bone-grafting procedures have been outlined previously herein.

Compound fractures present not only the well known hazard of osteomyelitis but also the frequent complication of delayed union. Our studies suggest that close apposition of the bone fragments is advantageous if severe periosteal damage is suspected. However, this should be done with a minimal amount of further soft tissue trauma.

SUMMARY

1. The importance of the periosteum is discussed from experimental and clinical aspects in relation to its role in normal fracture healing and prevention of fibrous union.

2. A critical analysis of 368 cases of fractures of the shaft of the tibia is presented, considering time of union, incidence and treatment of the major complications, and the effectiveness of various methods of treatment.

3. A comparative analysis of comparable groups of fractures uniting without complication following the initial form of treatment is made, indicating that the severity of the initial injury as evidenced by initial displacement of fragments, compounding and type of fracture is of maximum importance in deciding the method of treatment and in the prognosis.

4. A brief outline on the biometrics of shaft fractures of the tibia is described.

5. Using experimental and clinical data, proposals are made for the treatment of closed and compound fractures of the shaft of the tibia, and an indication is given that bone-grafting procedures should be reserved until six months have elapsed, if not done as a primary procedure.

Acknowledgment: We would like to acknowledge our indebtedness to the surgical staffs of the Toronto General Hospital and Sunnybrook Military Hospital for free access to their clinical material; to Mrs. Margot Hull and Mrs. Mary Murphy, medical artists; the Departments of Medical Photography at the Toronto General Hospital, the Toronto Western Hospital and the Banting Institute; and to Mr. Walter Cowan, curator of animal research, Banting Institute.

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Comparison of Ureteral and Renal Injuries

WILLIAM E. FORSYTHE, M.D. AND LESTER PERSKY, M.D., *Cleveland, Ohio*

From the Department of Surgery, Genito-Urinary Service, Western Reserve University, and the University Hospitals, Cleveland, Ohio.

THE proper management of renal and ureteral trauma is of obvious importance because of the potential loss of renal tissue and function and even at times, of life. In this age of increased vehicular use, it is not surprising that automobile accidents are a major cause of renal damage. Yet we find many injuries from falls and blows. Since all of these injuries are usually due to external force, we thought it would be interesting and informative to compare them with a group of genitourinary injuries which are iatrogenic or physician engendered, namely, ureteral injuries. A recent study [1] of such injuries in virtually the same hospital populations afforded an excellent basis for comparison. As a secondary aim we also hoped to determine if any changes were indicated in our current handling of renal injuries.

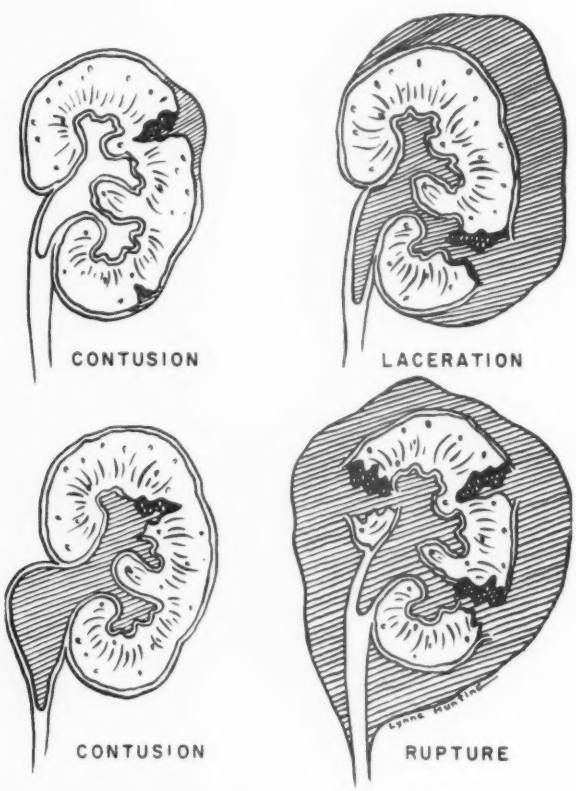

FIG. 1. Types of renal injury.

RENAL TRAUMA

In the management of patients with renal trauma there have in general been two divergent schools of thought. One group has a conservative, non-intervening attitude; the other has a more aggressive approach and favors early surgical exploration. The beliefs of the former group were well expressed by Sargent and Marquardt [2] who thought that no treatment was indicated in the majority of cases, and that only "signs of severe, progressive, exsanguinating hemorrhage" or "pyelographic evidence that the organ was shattered beyond any hope of usefulness" should lead to open surgery. Lowsley and Menning [3], as spokesmen of the opposite school believed that by early surgery much disability and ultimate renal loss might be spared the patient. They believed that gross bleeding of more than twenty-four hours was sufficient indication for prompt surgical intervention.

Our management has in general conformed to the former group, and we reserve surgery in most instances for those situations in which life is endangered from blood loss or in which there are secondary developments incompatible with the ultimate well-being of the patient.

There is general unanimity of opinion concerning the classification of renal injury. Three groups are generally discussed: (1) contusions, (2) lacerations, and (3) rupture or complete shattering of the kidney. Severance of the renal vessels is usually included in the latter group. (Fig. 1.)

Renal trauma must be suspected in every patient who has had injury to the thorax or

TABLE I
ETIOLOGICAL FACTORS

Etiology	No. of Cases	Percentage
Fall or blow	60	53.5
Automobile accident	43	38.5
Gunshot wounds	8	7.2
Stabbing	1	0.8

abdomen and this diagnosis should be considered even in the roentgenographic absence of skeletal abnormality. Physical signs may be minimal with only slight flank tenderness and no signs of peritoneal irritation, or there may be an easily recognized overt mass and the classical signs of peritoneal irritation with tenderness, rigidity and an abdomen silent to percussion.

Urinalysis is the first step in the definitive diagnosis and should be followed by urograms which are studied more for the determination of the anatomy and function of the contralateral organ than for evaluation of the status of the damaged kidney. If visualization is poor or if there is any question as to associated abnormality, we perform immediate cystoscopy and retrograde pyelography. Such examination under a topical anesthetic adds little to the patient's risk and may permit a more direct approach to a threatening, massive hemorrhage.

Our series of renal injuries was collected from the records of the University Hospitals of Cleveland and associated institutions over the last ten years, and is composed of 112 patients. The incidence classified according to the type of injury is as follows: there were eighty contusions (71.5 per cent), twenty-two lacerations (19.5 per cent), and ten ruptures (9 per cent). In the group there were seventy-eight males and thirty-four females (70 per cent and 30 per cent respectively).

Table I lists the etiological factors. Athletic injuries, which in large part were football accidents, are included in the falls and blows and account for 53.5 per cent of the total. Automobile accidents caused 38.5 per cent. The percentage of gunshot wounds (7.2 per cent) appears excessively high for a civilian institution in comparison with other series [4]. This may reflect the active nature of the Cleveland night life.

TABLE II
POSITIVE X-RAY FINDINGS

Nature of Finding	No. of Cases	Percentage
Contusion	28	37.5
Calyceal irregularity	15	
Delay of visualization	7	
Poor visualization	5	
Mass	1	
Laceration	12	57
Delay	3	
Mass	2	
Extravasation	5	
Intrapelvic clot	2	
Rupture	7	70
Non-visualization	6	
Delay	1	

In Table II are shown the nature and number of positive x-ray findings. Urography was not performed in every case, since occasionally the severity of the associated trauma or the minimal nature of the blow or symptoms did not warrant diagnostic studies. As expected, the greatest percentage of positive x-ray studies were in the group of patients who had the most extensive injuries. A similar situation is found when one compares the percentage of associated injuries. (Table III.) When the renal injuries were severe, i.e. rupture, there was associated trauma in 100 per cent of the cases. In these cases the associated trauma was also severe, whereas in contusions and lacerations the associated injuries were of a relatively minor degree, i.e. fractures, abrasions and contusions of the body wall.

The severity of these associated injuries is reflected in Table IV which shows the mortality figures for the various groups: there was no mortality for contusions, approximately 10 per cent in lacerations, and four deaths out of ten injuries (40 per cent), in ruptures. This increased degree of trauma is similarly shown in considering the operative procedures in the

TABLE III
ASSOCIATED INJURIES

Type of Injury	No. of Cases	Percentage
Contusion	22	28.6
Laceration	5	22
Rupture	10	100

TABLE IV
MORTALITY

Type of Injury	No. of Cases	Percentage
Contusion	0	0
Laceration	2	9.5
Rupture	4	40

various categories of renal trauma. (Table v.) Only eight cystoscopies were performed for contusions. No other surgery was necessary. For lacerations, there were seven operative procedures; roughly a third of the patients were explored. In ruptures, seven of ten or 70 per cent of the patients needed surgery.

There were a total of ten nephrectomies (8.9 per cent), three incisions and drainages, and one nephrostomy, fourteen operative procedures in all for an incidence of 12.5 per cent. After reviewing these figures we are still convinced that a conservative approach is the correct one and are reluctant to explore these patients earlier.

The other half of this study deals with ureteral injuries which usually occur as the result of surgical procedures, ordinarily pelvic laparotomy. The reported incidence of this complication varies in different series but appears to range from .5 to 1 per cent [5], [6]. However, when careful postoperative studies with urograms are carried out, this percentage increases to 2.5 or 3 [7]. When more radical pelvic surgery is undertaken, the incidence of ureteral injury has been reported to be as high as 30 per cent.

TABLE V
OPERATIVE PROCEDURE ACCORDING TO CATEGORY OF RENAL TRAUMA

Type of Trauma and Procedure	No. of Cases
Contusions:	
Cystoscopy	8
Lacerations:	
Incisions and drainages	2
Cystoscopy	1
Delayed nephrectomy	5
Rupture:	
Incisions and drainages	1
Nephrostomy	1
Nephrectomy	5

TABLE VI
THERAPY ACCORDING TO TYPE OF INJURY

Type of Injury and Therapy	No. of Cases
Ligation (12 cases):	
Deligation	1
Drainage	6
Ureteroneocystostomy	3
No therapy	1
Delayed nephrectomy	3
Section (11 cases):	
Primary anastomosis	7
Ureteroneocystostomy	1
Nephrectomy	3
Fistula (12 cases):	
Ureteral catheters	3
Ureteroneocystostomy	1
Ureterosigmoidostomy	1
Nephrectomy	4
Ligation of ureter	1

Thirty-five cases of ureteral injury were studied in our series. These have been classified as injury from ligatures, sections, and injuries resulting in fistula formation as shown in Table VI.

If, when the abdomen is open, any injury is recognized by the leakage of urine or by the visualization of a severed, torn structure, immediate repair is indicated. If a tie has been placed about the ureter this should be immediately removed, and if the ureter has been crushed, splinting with a ureteral catheter or T tube will obviate later leakage or stricture. When actual division has occurred, reanastomosis over a splinting catheter by end-to-end suture should be carried out. If repair is not possible, reimplantation into the bladder or into a flap of

TABLE VII
RESULTS OF URETERAL INJURIES

Results	Ligation (No. of Cases)	Section (No. of Cases	Fistula (No. of Cases)	Percentage
Good	6	4	4	40
Fair	1	2	1	11.4
Poor:				
Nephrectomy	3	3	4	31.4
Non-function	1	1	2	11.4
Died	1	..	1	5.7

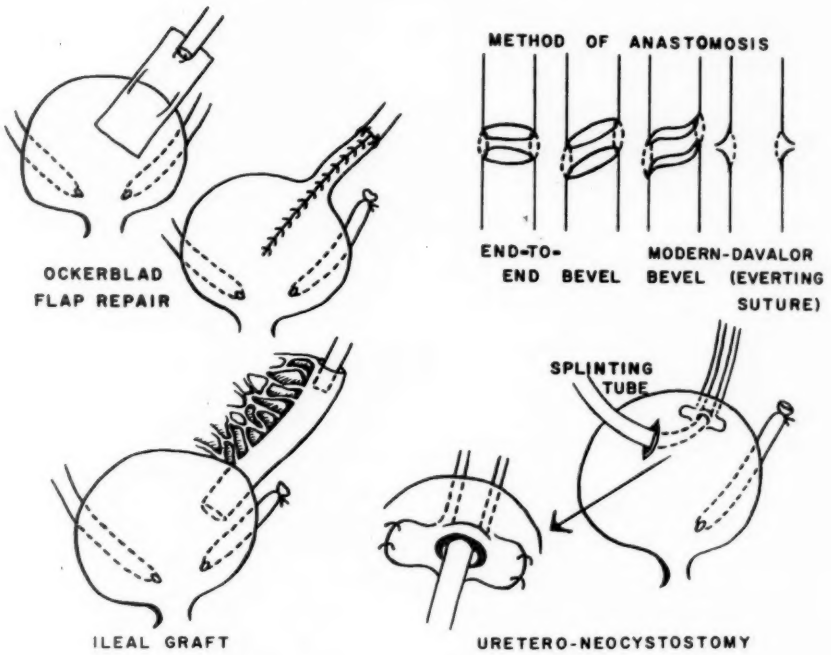

FIG. 2. Methods of repair of ureteral injury.

bladder may be necessary. Inadequate length is rarely found but if it should occur, repair utilizing a loop of bowel may be necessary. (Fig. 2.)

If the injury has been unrecognized, flank pain, fever and distension most commonly develop in the patient. Excretory urograms usually reveal the involved side. Cystoscopy with ureteral catheterization will disclose the obstruction or loss of ureteral continuity. When a catheter can be negotiated past the obstructing ligature and left indwelling, it will relieve the obstruction and may aid in healing.

At times, complete closure will ensue spontaneously. When the block cannot be passed, we favor preliminary nephrostomy which should at times be bilateral when anuria heralds a block on both sides. Definitive repair will usually involve ureteroneocystostomy or some form of ureteral graft at a later time. (Fig. 2.) Table VI gives the method of management in cases followed by our group. Table VII outlines the results. When ligation had been performed, seven of twelve patients ended up with a good result. There were, nevertheless, three nephrectomies. When the ureter had been transected, three nephrectomies had to be performed out of a total group of eleven cases. With fistula formation, four nephrectomies were indicated and only five out of twelve cases were deemed a good result.

It can be seen when comparing renal and ureteral trauma that those injuries occurring during elective surgery are attended by a very high morbidity and an extremely high percentage of reoperations—thirty-three further surgical procedures in thirty-five cases. There were ten nephrectomies in both groups, but in the case of ureteral injuries this approximates a third of the total number compared to 8.9 per cent in those patients with direct renal trauma. Mortality in both cases was about the same, slightly less than 6 per cent.

This leads us to our concluding remark which we think is a logical outgrowth of such a study as this, namely, prophylaxis is the single greatest weapon against ureteral harm. When extensive pelvic surgery is contemplated or if an extreme pelvic pathologic condition exists, the presence of ureteral catheters which can be easily palpated reduces to a minimum the likelihood of an unfortunate urinary tract accident. The cystoscopic passage of these catheters can be easily accomplished and adds little to the patient's discomfort or postoperative morbidity. However, when external renal trauma has occurred, a deliberate course of observation results in the conservation of renal tissue. These attitudes have been stressed by many urologists but need constant reiteration to spare the patient long periods of hospitalization and needless operative procedures.

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Complications of Closed Chest Trauma

C. Harold Cohn, M.D. and Robert R. Impink, M.D., *Reading, Pennsylvania*

From the Surgical Service of St. Joseph's Hospital, Reading, Pennsylvania.

In recent years there has been great emphasis placed on the management of the patient with closed chest trauma, either alone or associated with multiple injuries. This type of patient requires immediate evaluation of the extent of the injuries and a team effort in the management of resuscitation as quickly as possible. The thoracic injuries may be the primary concern in the treatment of the patient, or may be secondary in importance to some other bodily injury. However, the maintenance of an adequate airway and respiratory function are the primary considerations in all cases of severe trauma [*1*]. We have assembled a series of cases to illustrate the most common complications and associated injuries connected with closed chest trauma.

CASE REPORTS

Case 1.* T. Z. (No. 2147), a fifteen year old white boy, was admitted to St. Joseph's Hospital on July 9, 1958, a few hours after injury sustained while practicing pole vaulting during which he fell on a pipe protruding from the ground. He was ambulatory and complained only of pain in the right lumbar area where there was an abrasion, and superficial ecchymosis about 3 cm. in diameter. Roentgenogram showed a fracture of the tenth rib in the posterior axillary line. Otherwise, lung fields were clear. The patient's course was uneventful and he was discharged from the hospital on February 12, 1958. However, on April 22, 1958, the patient complained of pain in the right side of the chest, and x-ray examination revealed a massive pleural effusion or hemothorax. Thoracentesis performed at that time yielded 300 cc. of bloody fluid. After repeated thoracenteses, the lung was completely expanded and there was no evidence of residual pleural collection.

This illustration of the simple rib fracture is a very common occurrence and represents a mild form of disability. The hemorrhage probably occurred from a torn intercostal vessel which usually responds to simple management and thoracentesis.

* Case 1 is used by the kind permission of Dr. Paul Leisawitz.

Case 11. F. C. (No. 2340), an eighteen year old white boy, was admitted to St. Joseph's Hospital on April 19, 1958, after he fell from the fourth story of a college dormitory and landed on the grass below striking his left shoulder and chest. He had no history of loss of consciousness. Positive physical findings revealed deformity and tenderness over the left clavicle and severe tenderness over the anterior and lateral portions of the left side of the chest. At the time of admission to the hospital there was slight tenderness on palpation of the left upper quadrant of the abdomen. Peristalsis was normal. Roentgenogram revealed fractures of the left clavicle and of the fifth through eleventh ribs on the left side. There was no evidence of hemothorax or pneumothorax. Scout film of the abdomen showed considerable blurring of the soft tissues of the left upper part of the abdomen and serrated shadow was present along the greater curvature of the stomach. It was suggestive of a laceration of the omentum or a ruptured spleen. The patient's vital signs remained normal and his condition improved. Intravenous urogram performed April 21, 1958, was within normal limits except for haziness in the left mid-abdomen and blurring of the left psoas muscle margin. The patient was discharged from the hospital on April 25, 1958. He was completely asymptomatic when seen again on April 29, 1958.

The amount of trauma this patient sustained may well have given rise to associated intra-abdominal injury as demonstrated on x-ray examination. However, his clinical course remained satisfactory. It is possible that similar types of injuries may cause small areas of hemorrhage within the splenic capsule or within the omentum, which subside spontaneously; these areas of hemorrhage do not require surgical intervention.

Case 111. E. H. (No. 2356), a twenty-nine year old white man, was admitted to St. Joseph's Hospital on April 19, 1958, following an accident while

FIG. 1. Case v. *Left*, fractures of the midline and right ramus of mandible. *Right*, pneumothorax on the left side with mediastinal shift to the right.

driving a motorcycle. He had no history of unconsciousness but complained of pain in the left side of the chest and back. Physical examination of the chest showed tenderness over the lower half of the sternum and left lower side of the rib cage. In addition, there was extreme tenderness over the lower thoracic and lumbar spine. He had no evidence of any neurologic impairment of the lower abdomen and lower extremities. X-ray examination revealed fractures of the seventh, eighth and ninth ribs in the posterior portion but no evidence of hemopneumothorax. There were fractures of the anterior margin of the second lumbar vertebra and compression with anterior wedging of the body of the eleventh thoracic vertebra. The patient had moderate abdominal distension with nausea and vomiting during the first two hospital days. This subsided, and an intravenous urogram was within normal limits. The patient's vertebral fractures were treated with immobilization in a body cast. His subsequent course was uneventful.

This type of injury represents a common association of vertebral injuries associated with closed chest trauma [2]. This finding is seen in automobile or motorcycle collisions because of the sudden bending or twisting that is associated with this type of trauma.

CASE IV. F. S. (No. 995), a sixty year old white man, was admitted to St. Joseph's Hospital on February 15, 1958, with a history of being involved in an automobile accident in which he was thrown forcibly against the steering wheel. The steering wheel was broken from the force of the impact. He had considerable pain in his chest, especially on respiratory effort. In addition, he had a contusion of the nose and forehead. There was no definite history of unconsciousness. He denied any previous history of pain in the chest, indigestion or heart disease. Physical examination showed contusion and mild abrasion of the bridge of the nose. The only other positive finding was an area of contusion and tenderness over the left anterior lateral rib cage extending from the fifth to the ninth ribs. Roentgenogram of the chest revealed a fracture of the left eighth rib near the anterior axillary line. The patient was placed on a conservative regimen, and observed. An electrocardiogram performed on February 17, 1958, was reported as strongly suggestive of a high lateral myocardial infarction. An electrocardiogram repeated on February 20, 1958, was similar to the one performed three days previously. Serum transaminase determinations were normal and constant. The opinion at that time was that since there was no change in the record, this pattern had been established quite a while prior to the injury. The conclusion was that this man, at some time in the past, had a high myocardial infarction with a slight change in the anterior myocardium, all on the basis of coronary heart disease. The evidence at hand could not be considered acute or as a result of recent trauma. The patient was discharged from the hospital on February 21, 1958. A follow-up study of the heart was made on April 19, 1958, and this study was unchanged from the earlier records.

It seems advisable to obtain electrocardiographic studies in all patients who have had direct thoracic trauma, to rule out myocardial damage. The best time for performing this study of the heart is forty-eight hours after injury.

CASE V. S. S. (No. 3832), a three and a half year old white female child, was admitted to St. Joseph's Hospital on June 22, 1958, approximately twenty minutes after being struck by an automobile. She was unconscious and had a large hematoma of the forehead. Examination showed bloody cerebrospinal fluid flowing freely from her right external auditory canal. Her left pupil was more dilated than the right, but both reacted to light. The patient had multiple closed fractures of the mandible (Fig. 1, *left*) and a laceration of the left knee. There was a small area of contusion over the left clavicle. The patient regained consciousness approximately fifteen minutes after admission. Physical signs were otherwise completely normal. The laceration of the knee was repaired in the emergency room. The patient was seen at frequent intervals by a thoracic surgeon and a neurosurgeon. Approximately four hours after injury there was subcutaneous emphysema of the left side of the chest and neck. At that time (Fig. 1, *right*) x-ray examination confirmed the finding of a pneumothorax on the left side with mediastinal shift to the right, and a partial collapse of the left lung.

A catheter was inserted into the second anterior interspace and attached to an underwater seal drainage bottle. Her progress was satisfactory, and eleven days after injury operative reduction was performed on the mandible by an oral surgeon. Her subsequent course was uneventful and she showed no evidence of permanent cerebral damage. She was discharged from the hospital on July 12, 1958.

This is an illustration of the delayed finding of a tension pneumothorax and represents an outstanding example of the need for careful observation of the posttraumatic patient.

CASE VI. L. C. M. (No. 4068), a twenty-two year old white woman, was admitted to St. Joseph's Hospital on June 29, 1958, twenty minutes after being involved in an automobile accident. She had been riding as a passenger in the back seat. When first seen, she was in clinical shock and general supportive treatment was started. Examination showed multiple fractures involving both sides of the rib cage, including a fractured clavicle on the left side. (Fig. 2, *left.*) A catheter was inserted into the bladder and yielded a small amount of frank bloody urine. There was rigidity throughout the entire abdomen. She was given 3,000 cc. of whole citrated bank blood in the emergency room and roentgenograms were taken just before surgery. (Fig. 2, *right.*) At the time of abdominal exploration, the patient was found to have a compound fracture of the pelvis involving the bladder with extravasation of the urine into the extraperitoneal area, associated with a large extraperitoneal hemorrhage into the pelvic floor. The patient had a traumatic laceration of the spleen for which a splenectomy was performed. Because there was clinical evidence of continued loss of blood, two medium latex tubes were inserted into the left side of the chest and attached to an underwater seal drainage bottle. Seven hundred cc. of bright red blood flowed from the left side of the chest immediately after the tubes were inserted, but the flow diminished after the initial output. The patient received a total of 5,000 cc. of whole blood during the first twenty-four hours of hospitalization. She maintained a good renal output and subsequent studies revealed good renal function. She was discharged from the hospital on August 1, 1958, and has returned to normal activity.

The extreme nature of this patient's injuries is illustrated. It is interesting to note that despite all of her abdominal injuries and liberal use of whole blood, at no time did she have any suppression of her renal output [3]. I believe that this represents the successful immediate combating of shock and the good reserve of a young patient who has healthy kidneys.

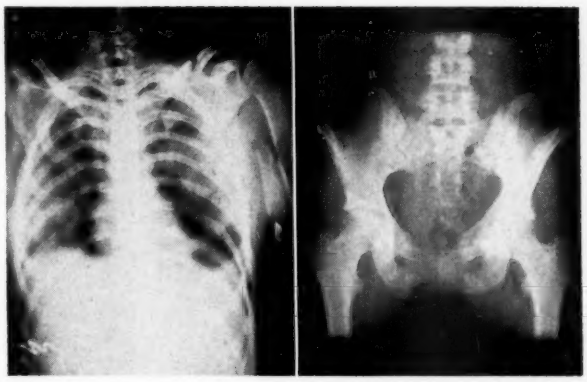

FIG. 2. Case VI. *Left,* fractured left clavicle with fractured ribs on both sides of the chest. *Right,* fractures of all pubic rami and left lumbosacral joint.

CASE VII. E. H. (No. 1), a thirty-eight year old white man, was admitted to St. Joseph's Hospital on January 1, 1958, following an automobile accident which occurred at 10:30 P. M. on December 31, 1957. He was trapped behind the steering wheel of an automobile which crashed into a tree. He was unconscious and in shock on arrival. Immediate examination revealed multiple lacerations and deformity of the mouth, mandibular area and face. Blood pressure was 60/30 mm. Hg, and the pulse rate was 132 per minute. Respirations were paradoxical with depression of the right anterior and mid-lateral chest wall, with subcutaneous emphysema present. (Fig. 3.) Examination of the abdomen was essentially within normal limits. There was a dislocation of the right hip. There were multiple contusions and lacerations of the upper and lower extremities. Tracheostomy was performed immediately, and a No. 24 French catheter was inserted into the right side of the chest and attached to an underwater seal drainage set. The dislocation of the right hip was reduced without anesthesia. (Fig. 4.) A Levine tube was placed through the nose and into the stomach for immediate suction. A Foley catheter was inserted into the urinary bladder. There were multiple fractures of the nose, maxilla and mandible. (Fig. 5.) In the emergency room the patient received 1,000 cc. of whole citrated bank blood and 250 cc. of plasma. The patient was seen in consultation by a neurosurgeon who did not believe that any intracranial decompression or other surgical intervention was indicated at that time. Repeated examination of the fundi showed no evidence of increasing intracranial pressure. An oral surgeon undertook the management of the facial and mandibular fractures. On January 28, 1958, plaster splints were applied bilaterally to prevent contractures of the lower extremities. The patient was maintained on tube feedings and excellent nursing care and finally regained consciousness on February 20, 1958. After he could tolerate an anes-

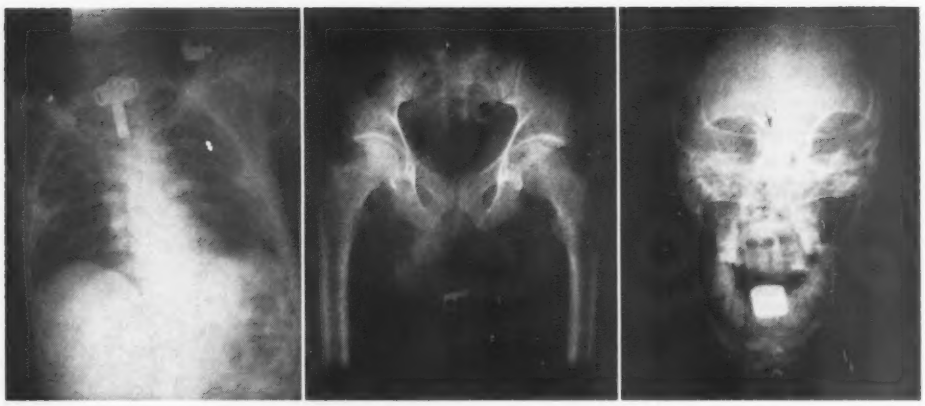

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FIG. 3. Case VII. Fractures of right chest wall.

FIG. 4. Same case. Postreduction x-ray film of dislocated right hip showing fracture of the acetabulum.

FIG. 5. Same case. Fractures of the nose, maxilla and mandible.

FIG. 6. Case VIII. Roentgenograms of the chest showing multiple fluid levels and barium-filled viscera in the left side of the chest.

thetic, his mandibular fractures were repaired with a Roger-Anderson external splint and plaster skull cap. In addition, the patient received general supportive therapy and antibiotics because of his urinary tract infection which developed after prolonged and repeated catheter drainage. The patient's final evaluation in June, 1958 showed that he had free motion of all limbs although there was some spasticity and mild contracture with atrophy. He had been receiving physical therapy which greatly improved his muscular status. Electroencephalogram performed on June 13, 1958, was reported within normal limits. He was discharged from the hospital on June 16, 1958, and was to be admitted to a hospital under the State rehabilitation plan for further treatment of his mental and physical status.

The team management of multiple injuries was once again utilized with the neurosurgeon, oral surgeon and thoracic surgeon all participating. Recovery was greatly aided by the physical therapy department and excellent nursing care. It is interesting to note that this patient, during his fifty days of unconsciousness and in the subsequent time when he was unable to care for himself, was placed on a mattress of alternating air pressure compartments which preserved his skin tone and kept him free of decubitus ulcers.

CASE VIII. A. S. (No. 1139), a sixty-two year old white man, was admitted to St. Joseph's Hospital on February 28, 1958, with a history of severe shortness of breath which had been increasing over a four-week period, accompanied by tiredness and peripheral edema. At the time of admission the patient had peripheral edema that had not completely resolved at bedrest. His past history revealed an accident approximately twenty-five years ago, at which time he was run over by a tractor and had severe injury to his chest. The patient did not know all of the details of this accident. Physical exertion revealed him to be extremely cyanotic and apprehensive. Breath sounds were absent on the left side of the chest. X-ray studies reported a massive pleural effusion in the left pleural cavity and further studies showed evidence of multiple fluid levels. Therefore, the diagnosis of diaphragmatic herniation of the left side of the chest was made. Barium enema and upper gastrointestinal studies revealed the greater portion of the stomach, small bowel and large bowel to be in the left side of the chest with good function of these organs except for mechanical displacement. (Fig. 6.) He was discharged from

the hospital on March 8, 1958, after refusing surgical intervention.

This case illustrates the chronic stage of traumatic rupture of the diaphragm which has been pointed out by other authors [4–8]. This patient's symptoms have been limited primarily to the displacement of the heart with interference of return blood from the inferior vena cava and from impaired pulmonary reserve.

CASE IX. M. R. (No. 7744), a sixty-six year old white woman, was admitted to St. Joseph's Hospital on December 13, 1957, with the chief complaint of shortness of breath, weakness and some pain and heartburn in the left side of the chest. These symptoms started five days prior to admission with a brief period of discomfort, after which she was able to follow normal activity. She had similar discomfort three days prior to admission and was diagnosed by her family doctor as having a mild respiratory infection. However, she became weaker and noted increasing dyspnea. She had no associated nausea nor vomiting. She was admitted to the hospital after her symptoms became more severe, with a diagnosis of congestive cardiac failure. Her past history revealed that on January 1, 1957, approximately eleven and a half months prior to her present admission, she had been involved as a passenger in an automobile accident following which she was admitted to another hospital in a semiconscious state. Because of her progressively deteriorating neurologic state, she had a bilateral cranial exploration on January 4, 1957, and was found to have bilateral hematomas, more marked on the left side. She made a good recovery except for some residual paralysis of the right upper extremity. At the time of the accident, x-ray examination revealed fractures of the left clavicle and fractures of the second, third and fourth left ribs. During the intervening months, she had mild pain in the right upper extremity and, on occasion, she had noted some intermittent heartburn. Physical examination revealed the patient to be acutely ill, pale and sweaty, and obviously in shock. Positive physical findings showed complete absence of breath sounds in the left side of the chest except in the apical region. There were a few rales present at the right base. Examination of the abdomen was entirely within normal limits. X-ray examination was reported as showing a massive pleural effusion in the left side of the chest with considerable mediastinal shift to the right. (Fig. 7.) Review of the roentgenograms and subsequent x-ray films with the patient erect showed multiple fluid levels in the left side of the chest, suggestive of a diaphragmatic herniation containing loops of bowel. Thoracentesis through the left anterior second interspace yielded bloody, foul-smelling fluid. With a preoperative diagnosis of diaphragmatic hernia with strangulated, incarcerated bowel, she was explored on December 14, 1958, through a left anterior thoracotomy incision through the fourth interspace. A combination of 1 per cent local procaine anesthesia was used with endotracheal oxygen and a small amount of intravenous sodium pentothal. Operation revealed massive gangrene of the fundus of the stomach with a grossly contaminated hemothorax. Through a separate abdominal incision, the fundus of the stomach was resected along with the spleen, and primary repair of an old traumatic rent in the diaphragm, which measured 3 cm. in diameter, was performed. The rent in the diaphragm was just lateral to the esophageal hiatus. The patient's postoperative course was marked by a febrile reaction and a steadily decreasing urinary output. The patient died at 1:45 A. M., December 16, 1957. Postmortem examination revealed acute pericarditis, probably toxic, with mild pulmonary edema; the cause of death was given as toxemia, secondary to left pleuritis.

FIG. 7. Case IX. Massive pleural effusion in the left side of the chest.

This case fits into the intermediate type of diaphragmatic hernia which has produced acute symptoms at some time after the occurrence of the traumatic diaphragmatic tear.

SUMMARY

The preceding cases have been used to illustrate various types of closed chest trauma and their complications. The need for team management for the severely injured patient is obvious. We have had good success with the cooperation of the neurosurgeon, urologist, orthopedist, thoracic surgeon, general surgeon, oral surgeon and physiotherapist. We believe that the immediate evaluation of the severely

injured patient is the joint responsibility of all members of the group involved, and while one member is responsible for the patient's care, combined efforts of all concerned will bring about a more satisfactory result.

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Is "Simple" Rib Fracture a Simple Injury?

JAMES H. COSGRIFF, JR., M.D., *Tonawanda, New York,* AND HARRY W. HALE, JR., M.D., *Buffalo, New York*

From the Departments of Surgery, University of Buffalo School of Medicine, and the Edward J. Meyer Memorial Hospital, Buffalo, New York.

RIB fracture is one of the most common injuries treated by the practicing physician today. The ribs are relatively superficial and unprotected and because of this and their anatomic configuration, they are particularly liable to injury. Many of such fractures involve only one rib and in the vast majority of cases are closed injuries. For these reasons, it is common practice to consider rib fractures routinely as minor injuries. However, because of the frequency and gravity of associated injuries and complications of rib fracture which often terminate fatally, it seems more logical to assume that all injuries to the chest wall are serious until proved otherwise. Then we shall adopt a method of management designed to disclose the more serious effects of injuries to the ribs and anticipate the complications and thus lead to a favorable outcome in most if not all cases.

ANATOMIC AND PHYSIOLOGIC CONSIDERATIONS

It is unnecessary to review the intimate anatomy of the thoracic wall and viscera at this time. Suffice it to say, that the ribs constitute an integral portion of the chest wall, lending rigid support to its muscles, nerves and vessels, and a bony breastwork for protection of the vital viscera contained within. While it serves as a guardian of life, so to speak, when intact, the ribs when fractured may become instruments of death.

The pathologic physiology of fractures of the chest wall has been demonstrated experimentally and documented clinically [1]. (Fig. 1.) Following fractures, the resultant pain causes splinting of the chest. Burford et al. [2] stressed the increase in pulmonary secretions occurring after such injury. The pain is usually severe enough to make it impossible for the patient to cough effectively, causing retention of secretions, atelectasis, pneumonia and finally death if the proper treatment is not instituted promptly. In addition to these alterations of pulmonary physiology, there are frequent associated injuries of thoracic viscera which may be of serious consequence. Rapport et al. [3], in a study of 730 patients with rib fracture, found a 41 per cent incidence of secondary complications. The mortality in their series was 5 per cent. Cameron and his group [4] noted complications in 65 per cent of their patients, with a mortality rate of 10 per cent.

It is apparent from perusing the surgical literature, that the mortality from rib fracture is directly proportional to the number of complications which ensue. In other words, prompt, efficient treatment based on sound surgical principles should significantly reduce the incidence of such complications and thereby lower the mortality.

MATERIAL

In the present study, 198 cases of bony or cartilaginous injury to the chest wall are re-

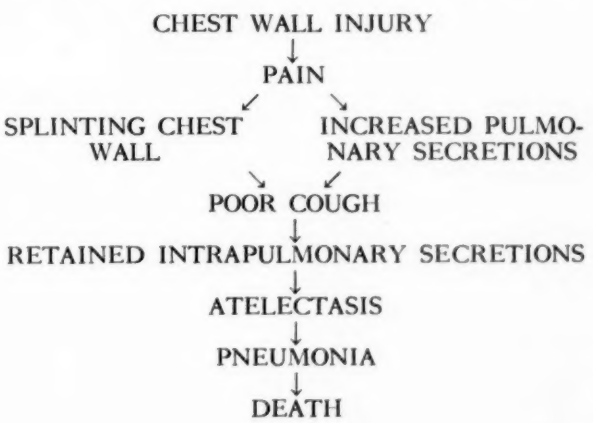

FIG. 1.

TABLE I
SEX DISTRIBUTION

Male	153
Female	45
Total	198

viewed. These included fractures of one or more ribs in 185 patients and injuries to the cartilage in the remaining thirteen patients. Males were injured approximately 3.5 times more frequently than females. (Table I.) The ages in this group ranged from thirty months to ninety-seven years.

MODE OF INJURY

As in other series, the most common mode of injury was by automobile accident, and in 40 per cent of the entire series injuries were incurred in this manner. (Table II.) An additional 35 per cent of patients suffered falls, and, interestingly, only 16 per cent of these sixty-nine patients fell or jumped from a height. Most of these patients were elderly people who slipped or missed their footing because of some unknown cause. In twenty-seven patients the cause of injury was unknown. This category includes those patients from whom no history could be obtained because of either associated cerebral damage or the effects of alcohol.

SITE OF INJURY

Of the 185 patients with rib fractures, sixty-nine had injury to the left side only, ninety had fractures limited to the right chest wall and twenty-six had bilateral fractures. (Table III.) Twenty-four per cent had one rib broken, while approximately one-third of the patients had more than four ribs fractured. (Table IV.) It is of further interest to note that two patients had fractures of ten ribs unilaterally, with one survival. Two others had a total of fourteen ribs fractured and one of these patients survived. One patient fractured fifteen ribs and lived. The majority of injuries involved the third through tenth ribs. (Table V.) There were two isolated fractures of the first rib and one solitary fracture of the twelfth rib.

TABLE II
MODE OF INJURY

Auto accident	71
Pedestrian	9
Fall	53
Fall or jump from height	16
Fight	16
Pleurisy	2
Squeezed about chest	2
Cave-in	2
Unknown	27

TABLE III
SIDE INVOLVED

Left side only	69
Right side only	90
Bilateral	26
Total	185

TABLE IV
NUMBER OF RIBS FRACTURED

One rib	44
Two ribs	49
Three ribs	28
Four or more	64
Total	185

TABLE V
RIBS FRACTURED

Rib No.	No. of Times Fractured	Solitary Fracture
1	11	2
2	35	6
3	43	3
4	62	3
5	64	2
6	76	4
7	86	4
8	76	6
9	71	7
10	49	5
11	23	3
12	11	1

ASSOCIATED INJURIES AND COMPLICATIONS

One hundred forty six patients had a total of 308 associated diseases, injuries and/or complications. Craniocerebral trauma occurred in thirty-five patients. The remaining associated injuries were primarily fractures. (Table VI.)

TABLE VI
ASSOCIATED INJURIES

Craniocerebral	35
Extremity fracture	20
Fracture of pelvis	10
Fracture of scapula	2
Fracture of spine	2
Fracture of sternum	2
Fracture of clavicle	8
Fracture of facial bones	3
Peripheral nerve injury	1
Total	83

TABLE VII
THORACIC COMPLICATIONS

Chest wall	28
Pleural	77
Pulmonary	50
Mediastinal	33
Total	188

TABLE VIII
CHEST WALL COMPLICATIONS

Subcutaneous emphysema	18
Flail chest	10
Total	28

TABLE IX
PLEURAL COMPLICATIONS

Effusion	33
Hemothorax	12
Pneumothorax	32
Total	77

Thoracic complications alone numbered 188. (Table VII.) Several interesting observations were made in this group. Two-thirds of the eighteen patients with subcutaneous emphysema had no detectable associated pneumothorax. Presumably, in these patients there was a laceration of the lung which was adherent to the chest wall, allowing egress of air directly into the adjacent soft tissue of the chest wall but without collapse of the lung. (Table VIII.)

Flail chest was a serious complication. Paradoxical motion of the thoracic wall developed in ten patients, and of these five died. In several cases, this complication was not apparent at the time of admission. However, as the patient's lung reacted to the trauma to the chest wall with increased secretions, poor cough, increasing dyspnea, etc., the paradoxical activity became obvious usually twenty-four to forty-eight hours later. We consider this period the most critical one in the course of the illness and stress the importance of close observation during the first two days after injury.

The pleural complications of effusion, hemothorax or pneumothorax occurred seventy-seven times. (Table IX.) Pneumothorax and effusion occurred together in nineteen instances. Most of the patients with pleural fluid were observed and checked periodically with chest roentgenograms. Thoracentesis was reserved for those patients with symptoms attributable to the fluid.

The thirty-two patients with pneumothorax comprise an interesting group from several aspects. The amount of pleural air varied from a small amount to that sufficient to produce a 60 to 70 per cent collapse of the lung. One patient had a tension pneumothorax. In eight patients, 25 per cent of this group, free air could not be identified on the roentgenogram of the chest taken on admission, but was found subsequent to intercostal nerve block. It is thus presumed that these eight patients suffered pneumothorax as a result of the therapy instituted. Although this seems to be a proper conclusion, it must be stated that delayed pneumothorax may occur in the normal course of events. When patients are relieved of pain by nerve blocking, their activity and respiratory movements are increased. As a result of motion at the fracture site, subsequent puncture of the lung by jagged rib ends may occur. Nine of the thirty-two patients required tube thoracostomy for lung re-expansion. Of the entire group with pneumothorax, five died.

Pulmonary complications occurred in fifty instances. (Table X.) These diagnoses were made primarily by physical examination or chest roentgenogram alone or in combination. It is fair to assume that the dividing line between pneumonitis and atelectasis on this basis may be a difficult one to define. It is of interest that among a group of 198 injuries to the chest wall, only four patients were thought to have pulmonary contusions.

The problem of non-penetrating cardiac injuries is noteworthy. (Table XI.) Cardiac contusion may present a serious complication of trauma to the chest wall [5]. The diagnosis seems to be made more frequently now than previously, probably because of improved methods of diagnosis, plus the fact that the surgeon is more aware of this entity. In the study by Rapport et al. [8], the incidence of

TABLE X
PULMONARY COMPLICATIONS

Contusion	4
Pneumonitis	30
Atelectasis	16
Total	50

TABLE XI
MEDIASTINAL COMPLICATIONS

Pneumomediastinum		3
Patients studied with electrocardiogram		53
Cardiac injuries:		
Myocardial contusion	18	
Possible myocardial contusion	7	
Abnormal electrocardiogram, probably unrelated to injury	5	

TABLE XII
ABDOMINAL COMPLICATIONS

Laceration of liver	5
Laceration of spleen	1
Laceration of kidney	2
Total	8

cardiac injury was 0.6 per cent. Knoepp found no such injuries in 386 patients with fractured ribs. It is encouraging that in this present study electrocardiograms were taken in fifty-three patients. In eighteen instances, changes were found which were compatible with a diagnosis of myocardial contusion. There were suggestive changes in the tracings of an additional seven patients. Although such conditions usually occur secondary to direct sternal trauma, as in injuries caused by the steering wheel, theoretically any blow to the chest wall may cause the suspended heart to abut against the vertebrae or sternum causing injury to the myocardium. Serial electrocardiograms combined with an appraisal of the clinical picture aid in making the diagnosis. The serum transaminase determination does not seem helpful in evaluating the extent of myocardial damage in these patients, because extensive damage to skeletal muscle usually seen in these people also produces elevation of the transaminase level.

Eight abdominal complications developed in five patients. (Table XII.) It is not implied that these visceral injuries were due to direct penetration by the fractured ribs but rather were probably the direct result of the injuring force.

MORTALITY

Among the 185 patients with rib fracture, there were twenty-one deaths—a mortality rate of 11 per cent! This seemed a rather excessive figure and an attempt was made to study these twenty-one patients in more detail. The nature of the injuries and clinical course were reviewed. The death was then classified according to whether injury to the rib was thought to be the primary cause, a contributory cause, or played no role in the death. When fatalities were analyzed in this fashion, it was believed that the rib fracture was a primary or contributory cause of death in fifteen patients. This brings the mortality rate due to injury to the chest wall down to 8 per cent. When grouped according to age, death was infrequent up to the seventh decade. The three patients in the eleven to twenty year age group

TABLE XIII
MORTALITY BY AGE*

Age (yr.)	No. of Patients	Deaths
0–10	2	0
11–20	14	3
21–30	12	1
31–40	38	0
41–50	33	1
51–60	31	2
61–70	29	7
71–80	24	4
81–90	14	3
91–100	1	0
Total....	198	21

* Under 50 years of age, 9 per cent; over 50 years of age, 17 per cent.

TABLE XIV
MORTALITY*

No. of Ribs Fractured	No. of Patients	Deaths	%
1	44	2	5
2–3	77	3	4
4 or more	64	16	25
Total.....	185	21	

* Over-all mortality, 11 per cent.

died primarily because of severe craniocerebral injuries, although in one of the three, the injury to the chest was a contributory cause. (Table XIII.) Correlating the mortality with the number of ribs fractured in each patient, a striking increase in the number of deaths was noted when four or more ribs were broken. (Table XIV.)

TREATMENT

Management of the patient with a fracture of one or more ribs should be carefully planned, keeping in mind the numerous associated injuries and/or complications that may occur.

A thorough appraisal of the patient's general condition by history and physical examination should preface any x-ray examinations. Anyone suspected of having a rib fracture should have nothing less than a roentgenogram of the chest taken while in the upright position. If his condition will permit, a more complete roentgenographic examination of the thorax should be

performed. Small amounts of free pleural air may be missed using the standard technique, but will be more obvious when an appropriate lateral decubitus study is performed. X-ray examination of the ribs is desirable in addition to the routine x-ray examination but are not vital to the planning of therapy.

Once the diagnosis is established, the question of proper treatment arises. Treatment must be tailored to each patient's needs. The most common symptom occurring after rib fracture is pain which is aggravated by respiratory or any other body movement. The irritated intercostal nerve may initiate the sequence of events depicted in Figure 1.

The use of adhesive strapping of the hemithorax is mentioned, only to be condemned. When used in the proper manner to control pain it restricts respiratory activity considerably besides being a nuisance to the patient.

Should every patient, therefore, have an intercostal nerve block? We think not. If the patient's pain can be satisfactorily controlled with mild analgesics, such are prescribed. However, if pain cannot be relieved with such medication or if the patient is in the older age group or has limited cardiac or pulmonary reserve, the use of intercostal nerve block is indicated. In addition, any patient with obviously impaired respiratory activity not relieved by the aforementioned drugs should also be treated with intercostal block. In many cases, one such block is sufficient to cause lasting relief from pain. Nerve block should be followed by another roentgenogram of the chest. Pneumothorax is not an unusual complication of rib fracture, and, as mentioned earlier, may result from the treatment.

Not all patients with pneumothorax require tube thoracostomy, and the decision to insert a chest tube should be based on the amount of free pleural air and the patient's respiratory status. If the lung is collapsed 20 per cent or more, we believe it is safer for the patient if an apical anterior chest tube is inserted intercostally, while the patient is under local anesthesia, and attached to an underwater seal. Further collapse is prevented, re-expansion usually occurs promptly and tension pneumothorax is impossible if the drainage tube is functioning properly.

Patients with extensive injuries to the chest wall are likely to have some degree of parenchymal damage with increased secretions. In addition to the measures previously mentioned, the use of aerosol bronchodilators and detergents is recommended and oxygen administered by tent, nasal tube or mask if indicated. Tracheostomy should be considered in patients with severe injuries to the chest who continue to have respiratory distress after institution of the previously mentioned measures, but it is not always an unmixed blessing since it deprives the patient of the power of speech, weakens the expulsive force of coughing and requires more diligent nursing care. On the other hand, it permits easier cleansing of the tracheobronchial tree, decreases the dead space of the respiratory tract and reduces the resistance to respiratory effort.

These benefits are particularly noteworthy by helping to reduce the paradoxical movement of the chest wall in patients with flail chest.

Open operation in this type of injury is restricted to those cases in which evidence points to injury to the intercostal artery or to pneumothorax persistent in spite of adequate intercostal drainage.

It is apparent from a review of the variety and frequency of complications consequent to injury to the chest wall that such injuries require the most careful consideration and management. Only a few patients can be treated safely on an ambulatory basis. The indications for admission to the hospital are as follows: (1) more than two ribs fractured, (2) any complication of fracture, (3) any associated disease of the chest, (4) any patient requiring nerve blocking, and (5) any patient with doubt as to the extent of injury. However, a safe rule is that which applies to most cases of trauma. When the question of admission arises, it should be recommended. A total of 85 per cent of patients in the present series were admitted to the hospital.

SUMMARY

1. A series of 198 patients with injuries to the chest wall is reviewed.

2. Eighty-five per cent of these patients required admission to the hospital.

3. One hundred eighty-eight thoracic complications were encountered.

4. In thirty-two patients pneumothorax developed, of which eight were delayed in onset and may have been complications of treatment.

5. Twenty-one patients died, and rib frac-

ture was thought to be the main or contributory cause in fifteen.

6. The mortality in patients over the age of fifty years was twice that of those under that age.

7. A program of management is outlined.

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Diagnostic and Prognostic Factors in Abdominal Trauma

ROGER D. WILLIAMS, M.D. AND ROBERT M. ZOLLINGER, M.D., *Columbus, Ohio*

From the Department of Surgery, The Ohio State University Health Center, Columbus, Ohio.

ONE of the most baffling problems in surgery can be the patient suspected of having an abdominal injury that requires surgical intervention as a life saving measure. All too frequently the more obvious multiple injuries to the extremities, head and thorax either mask or so greatly detract from the symptomatology of abdominal trauma that serious delays or a complete oversight of this injury occur. Several encounters with the latter convinced us of the necessity of reviewing our experiences with abdominal wounds. Were we missing the diagnosis of abdominal trauma because of the present day trend to call in a specialist to initiate treatment of the most obvious injury? This did not appear likely since a general surgeon is responsible for an over-all evaluation of the seriously injured patient. In order to determine the frequency of this type of trauma, as well as the diagnostic problems involved, a series of 200 consecutive abdominal injuries were studied.

MATERIAL

Between July 1, 1947 and June 30, 1958, 200 patients were admitted to the University Hospital with 273 abdominal injuries. Statistics in this group of patients differ little from the 297 cases reported by Allen and Curry [1]. Sixty-six per cent were between the ages of ten and thirty-nine years. There was a high male ratio of five to one (84 per cent males).

Figure 1 shows the number of injuries to various organs. The most common injuries were to the urinary tract (fifty-eight injuries to the kidney, eighteen to the bladder) and the intestinal tract (thirty-nine perforations of the bowel and twenty-eight mesenteric tears). There were 217 visceral injuries. Fifty-six injuries to the abdominal wall, diaphragm and retroperitoneal area, which were severe enough to pose diagnostic problems requiring hospitalization for over forty-eight hours, are also included.

Four out of five (79 per cent) of these injuries were non-penetrating. Nearly half (47 per cent) were due to automobile accidents and one-third (32 per cent) to injuries at home or work. Only one out of five (21 per cent) were penetrating wounds due to knife or gunshot injuries.

Of these 200 patients, eighty (or two out of five) had serious extra-abdominal injuries. These involved the extremities, head and thorax. In addition, thirty-nine patients (or one out of five) had more than one intra-abdominal organ injured. These are of great diagnostic and prognostic significance. Extra-abdominal injuries have caused delays in abdominal diagnosis because they are given first attention. These injuries rather than the ab-

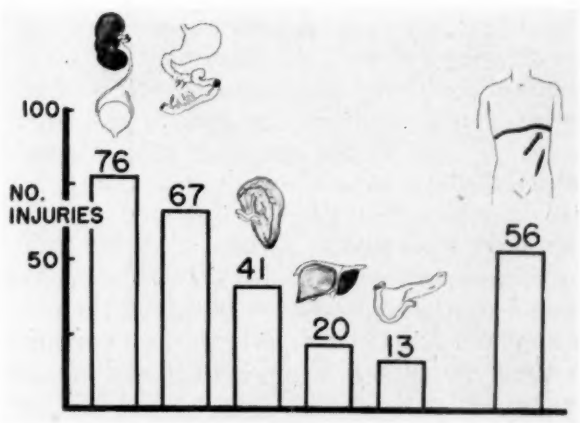

FIG. 1. Two hundred patients, two hundred seventy-three injuries. The 273 abdominal injuries are grouped in order of frequency. In addition to 217 visceral injuries, fifty-six retroperitoneal diaphragmatic and abdominal wall injuries which presented a diagnostic problem are included.

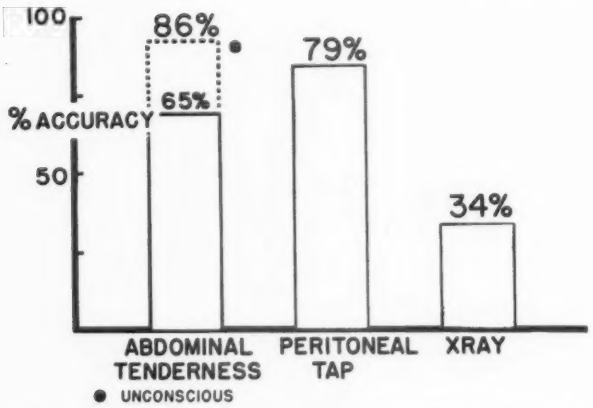

FIG. 2. Diagnostic factors. The diagnostic accuracy of abdominal tenderness is greater than peritoneal tap and x-ray examination if unconscious patients are eliminated. Despite the apparent accuracy of needle aspiration of the abdomen, this test often gives misleading results.

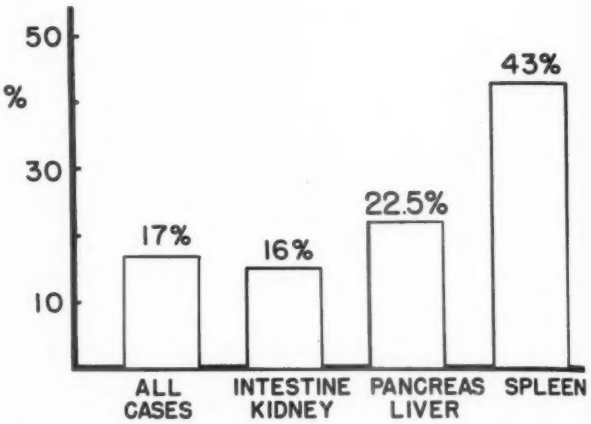

FIG. 3. White blood count greater than 20,000 per cu. mm. Although an elevated white blood cell count (over 20,000 per cu. mm.) is common with splenic injury, other injuries can also cause marked leukocytosis.

dominal injuries have usually been the cause of death.

The decision for surgery will be made early for penetrating injuries. Diagnosis is less difficult. This, plus the extent of thoracic involvement, has the greatest effect on prognosis. For these reasons further discussions of diagnostic and prognostic factors will be limited to the 157 patients with non-penetrating injuries.

DIAGNOSTIC FACTORS

Four factors have been evaluated for their diagnostic significance. These include abdominal tenderness, needle paracentesis (peritoneal tap), abdominal roentgenograms and the white blood count. Definite abdominal tenderness was noted in only 65 per cent of patients with non-penetrating injuries. If those patients who were unconscious on admission (thirty-five) are excluded, abdominal tenderness was noted in 86 per cent of the conscious patients with injury to the intra-abdominal organs. (Fig. 2.) This has not always been considered an indication for laparotomy. Perhaps it should be.

Needle paracentesis of the abdomen has been a routine procedure only during the past four years. It has been performed on one-fifth of these patients. A 10 cc. syringe and No. 18 gauge needle are used. When no blood is obtained in the region of maximum abdominal tenderness or muscle guarding, paracentesis has often been repeated in each of the four abdominal quadrants. This test has been accurate in 79 per cent of the patients on whom it was performed. Blood without intra-abdominal injury (false positive tap) was obtained twice when only retroperitoneal hemorrhage was found at surgery. No blood was obtained in three patients with ruptured spleen. Despite a relatively high degree of accuracy this test can therefore be dangerously misleading. Neither positive nor negative taps alone should be the sole indication for surgery or non-operative management.

X-ray films of the chest and abdomen were of diagnostic help in only one-third of these patients (34 per cent). They were of the most help in determining the presence or absence of injury to the kidney and bladder. They were of the least help with splenic, hepatic and pancreatic injuries. As an example, serration of the greater curvature of the stomach gas shadow which is considered a helpful diagnostic finding in splenic rupture has been noted more often when the spleen was undamaged than when it was ruptured.

Berman et al. have reported that an elevated white blood count above 15,000 per cu. mm. usually signifies a ruptured spleen or liver [2]. Seventeen per cent of the patients herein reported with abdominal injury had a white blood cell count above 20,000 per cu. mm. (Fig. 3.) This was of diagnostic significance only with rupture of the spleen. Even so, only 43 per cent of these patients had a white blood cell count in excess of 20,000 per cu. mm. A white blood count over 20,000 per cu. mm. has also been noted with injury to the head and chest, maxillofacial injury, and fractures of the extremities unassociated with abdominal in-

jury. Therefore this finding cannot be considered the sole criterion for laparotomy.

PROGNOSTIC FACTORS

Of greater diagnostic importance than any of the previously discussed factors are the extra-abdominal injuries which tend to mask the abdominal trauma. These are also of prognostic significance. In nearly two out of five patients there were injuries to the head, extremities and chest. Twenty-two per cent of the patients with non-penetrating abdominal trauma were unconscious.

In two out of five patients other injuries were treated for at least five hours before the abdominal injury was correctly diagnosed and laparotomy performed. This treatment of fractures, and injuries to the chest and head has been under the direction of orthopedic, thoracic and neuro-surgeons. It has been our policy during the past five years to admit all patients with multiple injuries to the general surgical service. In previous years all but five of the patients were seen by a general surgeon while the patient was still in the emergency clinic. No set team is appointed. The general surgeon usually acts as team captain under a plan similar to that advocated by Kennedy et al. [3]. Any consultant desired by the general surgeon is readily available.

Eighty-eight per cent of the twenty-four patients with non-penetrating wounds who died were in shock when received in the emergency clinic. All but five required blood transfusions of over 2,000 cc. Seven out of ten were unconscious. Of perhaps the most significance was a delay in diagnosis and treatment in half the patients who died. This delay was due to two factors, early attention to masking injuries (such as injuries to the head and chest), and delayed admissions of patients due to transfer from other hospitals.

Delayed diagnosis and treatment has not been responsible for a serious increase in mortality. The over-all mortality based upon the important prognostic factors in the 200 patients is shown in Figure 4. There were twenty-seven deaths (13.5 per cent). Eighteen of these patients, or two-thirds, had multiple serious injuries. Fourteen, or over half, had brain injuries which were the direct cause of death. It is doubtful that earlier treatment of the abdominal injury would have altered the outcome in these patients. Earlier diagnosis and more vigorous treatment might have altered the course in only four patients. Each had a single injury; two had ruptured spleens, one a ruptured small bowel, and one a ruptured bladder.

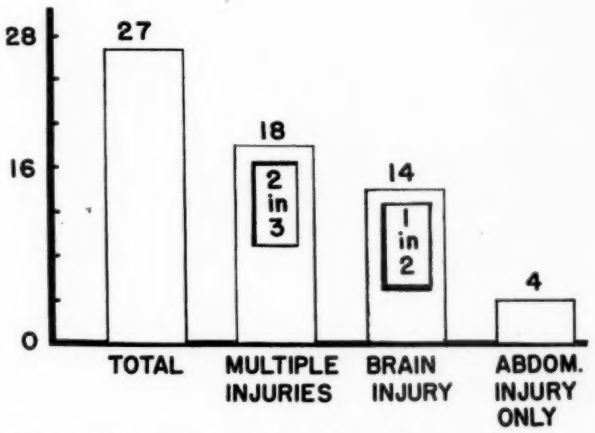

FIG. 4. Mortality. The over-all mortality in 200 cases was twenty-seven (13.5 per cent). Multiple injuries and injuries of the head were more important causes of death than abdominal injury in all but four patients in whom the abdominal injury was the sole factor.

COMMENTS

Excellent reports have been made in recent years on the over-all management of abdominal trauma [1,4–8]. Although these injuries are uncommon, correct treatment leads to early recovery in comparison with many fractures or serious injuries to the head. Laboratory tests are not as important in diagnosis as careful and repeated clinical examinations. In the 200 patients reported on herein, multiple extra-abdominal injuries were the cause of more deaths than the abdominal injury.

This review of abdominal trauma again points up the importance of multiple injuries and the need for team management as advocated by Kennedy et al. [3]. The paucity of abdominal injuries in comparison with other types has made accident-ward call less interesting to general surgeons and more interesting to other specialists. In this time of ultra-specialization fewer general surgeons are being trained to manage fractures and even fewer are accepting these cases in practice. However, if the general surgeon accepts the role of team captain in the management of multiple injuries he must carefully appraise all injuries. Abdominal injury is usually missed while more obvious injuries of the extremities, chest or head are being treated.

SUMMARY

This review of 200 patients with abdominal trauma stresses only the more important diagnostic and prognostic factors. Non-penetrating injuries present the greatest diagnostic challenge. Repeated careful evaluation of the abdomen in patients with multiple injuries is of the greatest diagnostic importance. Abdominal pain and the finding of intraperitoneal blood or fluid by needle paracentesis have been of more help than the white blood count or roentgenogram. X-ray studies have been of help in only a third of these patients. Elevation of the white blood count was seen more often with rupture of the spleen than with other injuries. A white blood cell count over 20,000 per cu. mm. has also been found with fractures and injuries to the chest and head even when the abdomen was not injured. In the individual patient this finding has therefore been of little help.

Multiple abdominal injuries and severe injury outside the abdomen are of diagnostic and prognostic significance. One out of five of these patients had two or more intra-abdominal organs injured. Forty per cent had other serious injuries outside the abdomen. These masking injuries of the head, chest and extremities were treated before the abdominal injuries in thirty-eight per cent of these patients.

The mortality in these 200 patients was 13.5 per cent. Severe shock, unconsciousness and a delay in diagnosis and treatment of the abdominal injury were frequent in the patients who died. Multiple injuries or damage to the brain have been as important as the abdominal injuries as the cause of death.

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DISCUSSION OF PAPERS BY DRS. FORSYTHE AND PERSKY; COHN AND IMPINK; COSGRIFF AND HALE; AND WILLIAMS AND ZOLLINGER

Lazarus A. Orkin (New York, N. Y.): I wish to thank Drs. Persky and Forsythe for the privilege of reviewing their paper prior to our meeting. They have presented to us their conclusions concerning certain controversial aspects of the management of renal and ureteral injuries.

No disagreement among urologists arises concerning the management of type I and II injuries (the contused kidneys) which require no treatment except rest in bed, or severe exsanguinating bleeding which demands emergency surgical interference. The main controversy arises when there is a rupture of the renal capsule (type III and IV injuries). This is the true rupture of the kidney which usually does not require immediate surgery. Drs. Persky and Forsythe believe that the correct approach in the management of this group should be a conservative one and they are reluctant to explore these patients. I believe, however, that these individuals should be operated upon.

The experimental findings of Sterling and Hands, Powers and others and our clinical experience with renal injuries stress the fact that while true rupture may at times heal without complication, this is the exception rather than the rule. As a proponent of early surgical interference, I do not wish to imply that this means nephrectomy but rather an attempt to conserve the kidney by drainage and arrest of bleeding. My belief is that comparatively early surgery after the period of shock is past should decrease the mortalities and nephrectomies. This view is borne out by our experience in a series of thirty-nine patients with true ruptures who were operated upon; there were two deaths and only one instance in which we had to perform secondary nephrectomy. This view is also strengthened by the following illustrative cases. A patient with a rupture of the right kidney was treated conservatively. Five years later, there was a large cyst with a deformity visible on pyelogram. Another patient had a rupture of the left kidney which was treated conservatively. Three years later, there was a functionless left kidney with a renal calculus. Nephrectomy was performed. A chemical analysis of the calculus revealed a blood clot as its nidus. In a third case the kidney was explored and the rupture

repaired. The result was highly satisfactory. In yet another case the kidney was explored and the rupture repaired. The end result, two years later, is good.

In Drs. Persky and Forsythe's series there were eight cases of laceration and seven of rupture. Ten patients came to nephrectomy and the mortality for this group was 49.5 per cent. Perhaps both of these figures could be reduced by earlier surgical interference.

To summarize renal injuries, my belief is that the conservative approach is to operate on a patient with a ruptured kidney, and the radical approach is to leave him alone.

Drs. Persky and Forsythe believe that one of the most important consideratons in the problem of ureteral injuries is prophylaxis. This they would accomplish by the presence of indwelling ureteral catheters. This is a highly controversial procedure. I do not advocate preoperative uretral catheterization because I believe that it is a superfluous procedure which is not entirely free of danger. It often gives one a false sense of security since it is very frequently difficult to locate or palpate the ureteral catherer during the operative procedure. The presence of the catheter is no guarantee against injury for we have all heard of ureteral fistulas that have developed under these circumstances. The best prophylaxis is for the pelvic surgeon to learn the characteristic rubbery feel of the ureter and always to expose and visualize it throughout the operative procedures.

A review of their results in ureteral injuries is disconcerting and illustrates how serious the problem really is. In their series of thirty-five cases, a poor result was obtained in sixteen, nephrectomy had to be performed in ten (31 per cent), nonfunction of the kidney occurred in four (11 per cent) and there was a 5.7 per cent mortality. It is difficult to comment on these figures without an analysis of the individual patients, and without knowing certain important criteria such as: what was the original pathologic condition, did the ureteral injury occur during the extirpation of malignant disease, and was the ureteral injury discovered during the operation or at some time afterward? In general it may be said that our results with ureteral trauma might be improved by the following methods: First, by recognizing the injury at the time of its occurrence. This can best be done by always isolating and visualizing the ureter throughout the original operation. Second, in the postoperative period by being constantly suspicious of the possibility of a ureteral injury and by performing excretory urography as soon as this suspicion arises. If a ureteral injury is present, it is my belief that definitive repair of the ureter should be left to a later and more propitious time, and during the period of watchful waiting one should protect the kidney from further destruction by diverting the urinary stream of the affected kidney, preferably by nephrostomy.

HARRY W. HALE, JR. (closing): Dr. Cosgriff and I realize that our subject is not a new one, certainly to this organization, and we do not claim to have any very radical ideas or new inventions to present. However, we think there is still a need to emphasize the potential severity of chest injuries even though at first and superficially they may seem to be simple or even trivial. We see evidence of that need in our locality and believe that it is important to emphasize the complications and dangers of rib injury and the need for a well organized system of handling such injuries based on the pathologic, pathophysiologic and therapeutic requirements of each case.

Our series is, of course, a hospital series and one may say that this will perhaps overemphasize the severe aspects of the disease. However, most of our patients are people who come unreferred by other physicians; they either walk in or are brought in by police or ambulance and are, hence, essentially unselected. Therefore, I do not think that criticism is too important.

We have seen a number of patients who were given a casual once over by our own men and by others and who have returned later with obviously much more severe injury than was at first suspected.

Dr. Cosgriff mentioned the use of tracheostomy in this series. It was used thirteen times, and although he mentioned that it is not an unmixed blessing, nevertheless we do not hesitate to use it when indicated (particularly in extensive chest wall damage with flail chest), because it is certainly a boon to the treatment of these individuals. It is not an easy way out and it does not reduce the nursing care. It simply makes that care easier by facilitating the performance of tracheal cleansing.

Dr. Cosgriff did not mention open operation which was not carried out in this series, but perhaps should have been in the case of one patient who came to us four days after injury in a wild state of delirium tremens and died within a few hours from a massive hemothorax. Open operation in closed chest injuries is reserved only for persistent bleeding from a lacerated intercostal artery which was the case in this one individual.

Again, we would like to emphasize the need for observation of these patients particularly in the first forty-eight hours after injury and the need for hospitalization when there is any question at all about the patient's condition.

GEORGE JAMES CURRY (Flint, Mich.): I have had the privilege of reading the excellent paper by Drs. Williams and Zollinger. I have nothing but words of approval. It is balanced and rationalized. The emphatic statement of the necessity of having a team captain and a good, skillful general surgeon meets my approval. I think there is ofttimes too

much delay in beginning the care of patients with serious injuries.

I would like to comment on Drs. Cosgriff and Hale's paper in which (it was my impression), Dr. Cosgriff said that tracheostomy is not too popular. We like to think in our hospital that "tracheostomy should be performed when you think of it," and it has been increasingly used over the last ten years. We are certain that it can do no harm, and it draws the attention of the nursing personnel and the house staff a little closer to the patient's care.

I would also like to emphasize that sometimes we wait too long to take care of the affiliated injuries. Of course, we are charged with the saving of a life, and the intra-abdominal injury is always serious. There is no need to say that it needs to be recognized early, but care of the associated multiple fractures is sometimes delayed too long. They can be cared for, by at least some type of management such as stabilizing, almost coincidentally with the management of the other severe injuries.

We have many times taken care of severe fractures of the lower extremities in the presence of severe craniocerebral injuries. This, of course, demands the facilities and skills of a good department of anesthesia; the additional anoxia is offset by the fact that something is done for a condition that certainly is an aggravating factor to the general physiology of the patient.

Rudolf J. Noer (Louisville, Ky.): The theme, the patient with multiple injuries, has been referred to in all the papers presented but I think it deserves more emphasis than has been given.

Your President last year [Dr. Johnston] referred to the increasing tendency toward specialization in the field of surgery and to the possible evils in this system. The surgical specialties as we know them today were developed through the special interests of general surgeons. Unfortunately we see an increasing tendency toward restriction in these training fields. I hope that we may before long reverse this and return to the time when surgeons are surgeons first and specialists later.

Patients do not become injured by systems or organs. They are injured as patients. If we are going to give them proper care, they need to be under the care of one who understands the patient as a whole and is not unduly concentrating on one system.

Jonathan E. Rhoads (Philadelphia, Pa.): I would like to comment on the paper by Drs. Williams and Zollinger which recommended the use of puncture of the abdominal wall as a diagnostic procedure. This is a procedure we have been interested in since Arnheim published his recommendation of it in 1934. I was glad that stress was placed on the use of a spinal needle because they are short-beveled needles. If you employ an ordinary needle such as many of those used for intravenous infusions and put it through the abdominal wall, it is quite possible to stick a viscus.

I tried this out on a patient undergoing laparotomy. Just before opening the peritoneum I pushed a needle through the abdominal wall so that when the peritoneum was opened one could see where it was, and we found it sticking in the wall of the transverse colon.

If you review the earlier literature of intraperitoneal injections prior to the time when intravenous infusions were widely used, you will find a record of a number of disasters, although whether these resulted from using the wrong kind of needle or from other factors is hard to decide.

I think this is the most extensive series of diagnostic paracenteses yet to be published. Furthermore, they have used the method more thoroughly than most persons, sometimes puncturing each of the four quadrants.

I would like to ask the authors whether they have had any instance in which they thought it was harmful.

Lester Persky (closing): I would like to thank Dr. Orkin for his discussion and point out to the group that if they did not know what makes horseracing, they do now.

As far as the management of renal injury is concerned, there are theories on both sides which advocate either early intervention or a conservative approach. I do not think that it is possible to transpose completely experimental work on renal injuries in the laboratory to the clinical situations in which things are compounded by associated trauma. Similarly, I do not think that the urologist who is asked to see ureteral injuries has really very much control over the palpation of ureters or familiarity with the area as the palpation is performed by the general surgeon or the gynecologist.

We are asked to see the complications and we believe that to reduce the incidence of these complications the presence of ureteral catheters is a great comfort to the surgeon.

James H. Cosgriff, Jr. (closing): Dr. Curry referred to the surgical adage "The time to perform tracheostomy is when you think of it."

We are not afaaid to perform tracheostomy in Buffalo, but we think it is a procedure that is not to be taken lightly. It does have certain disadvantages and certainly increases the need for better nursing care. If this is available, fine, we think it should be performed. In many situations, however, such nursing care is not available, and we have found in these instances that it may be more detrimental than beneficial to the patient.

Roger D. Williams (closing): I would like to thank Drs. Curry and Rhoads for their discussions. Dr. Curry has always emphasized to me

the need for doing it now; and I think that I should perhaps emphasize that many of our patients for whom treatment of extra-abdominal injuries may have delayed the diagnosis of abdominal injury were being treated by the "do it now" method of treating all injuries at the same time. It simply emphasizes that one should carefully re-evaluate from time to time the possibility of an abdominal injury.

In answer to Dr. Rhoads' question, whether peritoneal tap is harmful, I cannot tell how many peritoneal taps we have performed over the past ten years at University Hospital, but it is quite a large number. We perform peritoneal tap quite often for suspicion of pancreatitis and mesenteric thrombosis as well as for suspected abdominal injury. To my knowledge, although we have punctured an abdominal viscus (particularly the small and large bowel), I know of no case in which it has produced any untoward effects. On one occasion when I personally punctured the abdominal wall and the small bowel and explored the patient within the next hour, there was no leakage, even with distention of the bowel. In this case we were using the short needle, and I certainly want to emphasize again the use of a dull needle even if one first has to make a little nick in the skin to get it through.

Gas Gangrene

CLINICAL INFERENCES FROM EXPERIMENTAL DATA

LIEUT. COL. DOUGLAS LINDSEY, M.C., *Edgewood, Maryland*

From the Traumatic Investigation Branch, Biophysics Division, Chemical Warfare Laboratories, Army Chemical Center, Maryland, and the Division of Surgery, Walter Reed Army Institute of Research, Washington, D. C. This article does not represent the official position of the United States Army or any element thereof. The data from which the inferences are drawn were obtained through experiments performed in the laboratories of the Biophysics Division, Chemical Warfare Laboratories. The individual experimenters cited in the references [1–11] were personnel of the Chemical Warfare Laboratories or personnel of the Division of Surgery, Walter Reed Army Institute of Research.

GAS gangrene is more of a potential hazard than it is an immediate problem. Nevertheless, even if we disregard the threat that gas gangrene may appear in epidemic or endemic form under unusual circumstances, such as in war or major natural disaster, sporadic clinical cases of gas gangrene are sufficient to give the disease a prominent place in the mind of any practitioner of the surgery of trauma.

In the normal course of clinical practice, the incidence of gas gangrene is fortunately low enough that it is unusual for a single surgeon to amass a large series of personally observed cases. It is even more difficult to make detailed or definitive comparisons between cases since there is likely to be a wide variation between individual patients with respect to the size, location and type of wound, the time of onset of the infection, and the time of diagnosis and treatment.

Over the past few years, extensive studies [1–11] have been made in these laboratories of the mechanisms of death from a standardized wound in the goat. The preparation is a massive open wound in the hindquarters, produced by the detonation of high explosive in immediate contact with the surface of the extremity. (Fig. 1.) Although the buttock and thigh are presumably non-vital areas, these animals die, if untreated, with remarkable uniformity: the mean survival time is about twenty hours, with a standard deviation of about five hours.

In terms of pathological anatomy and physiological response, the wounds are entirely comparable to experimental wounds produced by high velocity bullets [1]. There are no data on which to base a comparison between these violently induced wounds as seen in the laboratory, and wounds due to lower velocity crushing and tearing such as are seen in the typical industrial or vehicular accident.

The preparation was developed to be, and has been studied as representing, an experimental model of traumatic shock such as is seen on the battlefield [2–5]. It may be, however, that it is in truth distinctly atypical: the more recent studies [6–11] have confirmed a long-standing suspicion [4,5] that severe clostridial infection in the wound is a characteristic component of the natural course following wounding. Along with the degree of reduction in circulating blood volume (presumably representing the severity of the "shock"), the concentration of pathogenic clostridia in the wound (presumably representing the severity of the infection) is a highly significant index of survival time [10].

Whether or not this preparation is really representative of the course of events in typical wounds of battle is not relevant to this paper, for it is clear that it does represent severe clostridial infection in muscle. The simultaneous presence of wound infection and wound shock does complicate the experimental problem, but such a combination is not unusual in clinical practice.

In our laboratory studies the animals are observed closely from the moment of wounding until death; there is no period of lost observations pending admission, transfer, or consultation. The animals are studied in accordance

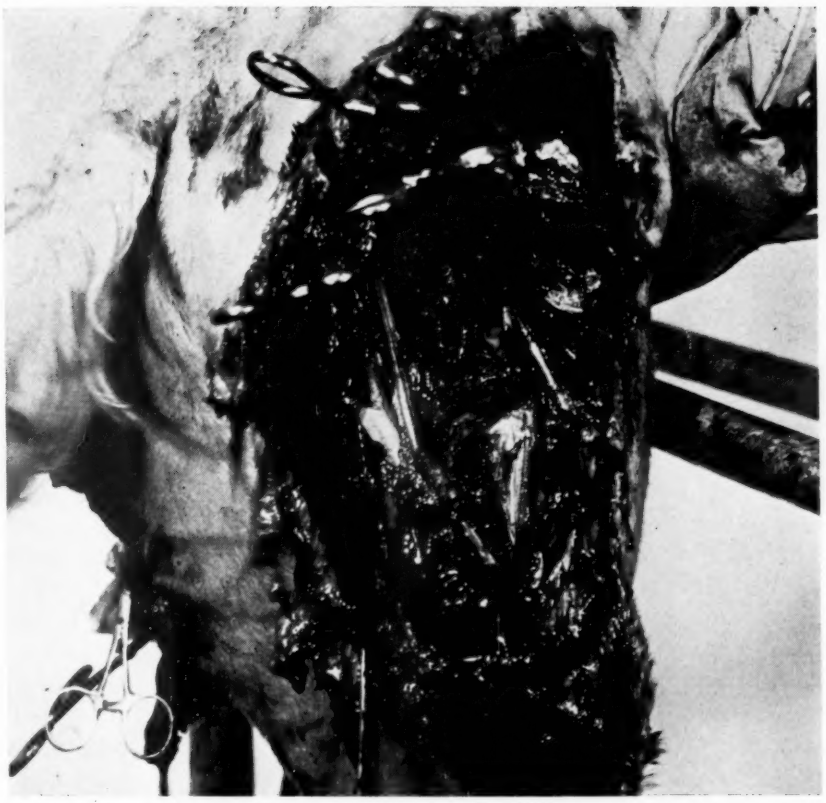

FIG. 1. The standard wound, immediately after detonation of high-explosive pellet on surface of lower thigh. (U. S. Army Photograph.)

with a comprehensive and uniform pattern of diagnostic and therapeutic procedures. The wounds are all of the same size, type and location. The animals show a consistent physiological response so long as they are subjected to a given set of experimental conditions. Modifications in experimental treatment can be introduced as controlled variables. Survival time is accurately determined, and offers a tangible and readily quantitative criterion of the effectiveness of treatment.

These advantages of the study of clostridial infection in this laboratory preparation, in comparison to some of the frustration inherent in analysis of clinical cases, give promise of complementing the knowledge of gas gangrene which is gained from clinical experience. Recent intensive studies of the infectious process in over 300 animals, and the reports of earlier experiments involving several thousand more animals, offer a valuable pool of data. A review of these data may be worthwhile to the practitioner of the surgery of trauma. It is difficult to overemphasize the ever present pitfalls in extrapolating from animal experimentation to human beings, but so long as due notice of caution is explicitly given, some of these inferences may be of practical value in clinical surgery.

DIAGNOSIS

Gas and Odor. It is generally accepted that gas is not an essential or necessarily prominent manifestation of gas gangrene. Even so, the name of gas gangrene is well fixed, and it is likely to be with us for some time. Certainly it is not much more inaccurate than its predecessor terms: "traumatic" gangrene, "fulminating" gangrene, "invasive" gangrene, or "galloping" gangrene [*12*].

In the wounds of these goats, gas is not often seen short of twenty-four to forty-eight hours, and by the time gas is evident the animal is often near death. Knowing that I am constantly studying an experimental clostridial infection, when I look at these animals twelve to eighteen hours after wounding, I must admit that I would certainly miss many early diagnoses if presented with comparable wounds on the ward.

It may be that the workers in our laboratory have become inured to the smell of putrefac-

FIG. 2. Same wound as illustrated in Figure 1, seventeen hours after wounding. Animal *in extremis* from severe Clostridium perfringens infection in wound. Note absence of gross evidence of infection and minimal change in comparison to Figure 1. (U. S. Army Photograph.)

tion, or that their olfactory senses are overcome by the natural pungent odoriferousness of the Texas Angora goat. Nevertheless, we have not been impressed with the usefulness of the odor of the wound as a diagnostic criterion. It is our impression that, except in the later and really obvious stages of the disease, severe infection with Clostridium perfringens is often almost without odor, either foul or diagnostically distinctive. An early and prominent odor may be associated with Cl. perfringens infection when the infection includes other clostridia (pathogenic or non-pathogenic), Pseudomonas, coliforms, or fecal streptococci. At any rate, experience with this animal preparation confirms that the absence of a notable odor does not militate against the diagnosis of even a severe Cl. perfringens infection.

Appearance of the Wound. Development of a typical gangrenous appearance in the wounds of these animals appears to require a minimum period of time; within this period the appearance of the wound is not in proportion to the severity of the infection. At about twelve to sixteen hours after wounding, few animals have a wound of nasty appearance. The wounds containing 10^4 clostridia per ml. in an animal treated with penicillin and the wounds in an untreated animal containing 10^8 clostridia per ml. (10,000 times as many organisms) are quite comparable on inspection and exploration. At about sixteen hours, occasionally earlier, the lacerated surfaces of muscles become rather mushy, and intact muscle bellies sometimes become pale and slightly gray. Even so, the muscles are not friable, they bleed freely when cut, and they retract when stimulated.

In Figure 2 is illustrated a typical wound at seventeen hours after wounding. This is the same wound illustrated in Figure 1, and in comparison with the appearance immediately after wounding the change is not remarkable except that the later wound is dry. Color films revealed a purplish tinge to the intact belly of the vastus lateralis which was not noticed with the naked eye. In spite of the innocuous appearance of the wound from the standpoint of currently active infection, a swab sample

of the exudate deep in the muscle revealed a concentration of 10^8 Cl. perfringens per ml.: one hundred billion Cl. perfringens per L., certainly a potent toxigenic focus!

Up to about twelve to sixteen hours after wounding, most of the wounds remain dry. If the dressings are stained at all, they are stained with fresh blood. Beginning at about sixteen to twenty hours after wounding a thin serosanguineous exudate appears; it seldom appears in pure serous form unless hemostasis has been quite meticulous and the initial bloody dressings have been replaced with clean ones.

After about twenty-four hours the exudate begins to change character, and by thirty-six hours it is usually thick, and brownish or copper colored. It may be scanty, or it may be quite profuse. By thirty-six hours the muscles directly involved in the wound are patently non-viable; they are brown-red and mushy. Muscles on the edge of the wound (such as the vastus lateralis shown in Figures 1 and 2) are distinctly edematous and quite friable: a standard cotton swab can be thrust through the muscle without breaking the applicator. Even so, the muscle still contracts when mechanically stimulated, and it bleeds freely when cut.

By about forty-eight hours the muscles on the edge of the wound are obviously nonviable, and muscles deep in the wound are partially liquefied. The exudate is then a suspension of degenerated tissue, and grossly bears a striking resemblance to black bean soup.

Clinical and Laboratory Data [*1,9*]. The wounded animals do not show a marked febrile response. They may be afebrile; they may show a temperature elevation of 1 or 2 degrees above normal, but they may show an exactly comparable elevation if just simply subjected to tracheostomy for measurements of respiratory functions. We have little data on the general response of the goat to other types of infection.

The white blood cell count does not show a consistent response: it may be slightly elevated or slightly depressed. There is a marked depression of circulating blood volume, beginning shortly after wounding. There is a slightly greater depression in red cell mass, apparently due to loss of whole blood into the wound or through the wound.

The red blood cell count, hemoglobin, and hematocrit are slightly depressed—consistent with loss of circulating blood volume, and compensatory hemodilution—but there is no evidence of intravascular hemolysis. The stroma of the red cell in the goat does not contain lecithin, and consequently is not susceptible to lysis by a lecithinitic toxin [*13*], but I do not think that the absence of hemolysis in this wound preparation is necessarily so simple a matter. My own clinical experience with human gas gangrene is limited; I call for support from a clinician with enormous experience: contrary to some popular statements, intravascular hemolysis is an unusual occurrence in clostridial infection of muscle [*14*]. In clostridial septicemia it is a usual occurrence; in clostridial infection of muscle, it is an unusual occurrence.

Cardiac output falls rather consistently throughout the clinical course. The major respiratory change is a shallow tachypnea.

Insofar as we are able to appraise the psychology of the goat, the animals do not appear to suffer pain, nor is the wound remarkably tender. The animals usually remain alert, or even apprehensive, until about the last 10 per cent of their span of survival, when a few, but not most, appear to become drowsy. In the late stages the animals often appear weak, with difficulty in holding the head erect; in spite of this weakness, the terminal event is often not a quiet death, but it may be marked by the increase in apparent anxiety and a few minutes of nearly manic behavior. Sometimes the terminal event is an opisthotonic convulsion. Rigor mortis occurs within a few minutes after death, sometimes before the corneal reflex finally disappears.

In sum, the systemic "clinical" picture in the course of this experimental infection is not unlike that seen in human beings with gas gangrene, but, in the early phase particularly, it is not at all distinctively diagnostic. We have not been impressed with the ease, the accuracy, or the probability of making an early diagnosis in these animals on clinical grounds.

Bacteriological Data [*6*]. Our experience is at variance with the published opinion of many microbiologists that bacteriology is of little value in initial diagnosis, and that it is essentially limited to confirming a clinical diagnosis and establishing the species of the organisms involved. I personally feel that bacteriology can be a primary tool in early diagnosis, but I limit this confidence to quantitative bacteriology.

Qualitative cultures and qualitative reporting of examinations of direct smears may be quite misleading. Clostridia are ubiquitous, as

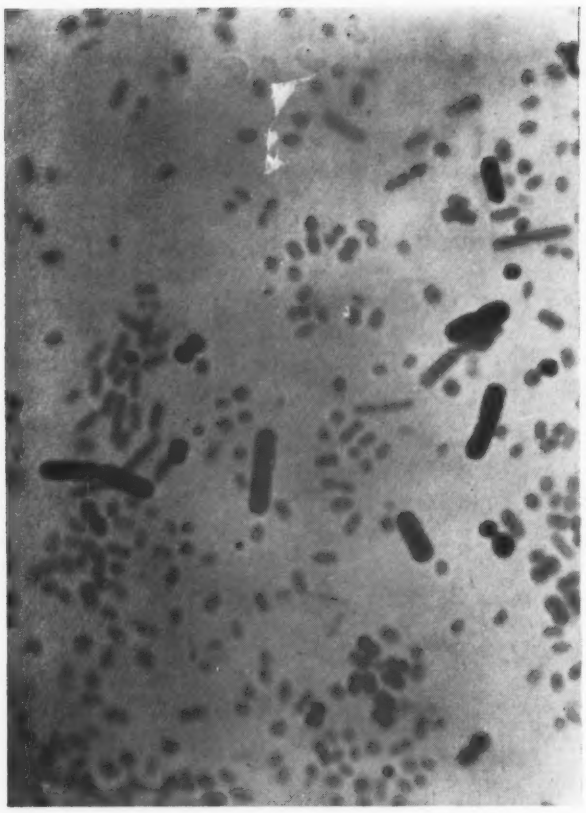

FIG. 3. Cleared smear of exudate from standardized wound of goat. The predominant organisms are gram-negative rods, but the biologically significant organism is a gram-positive rod.

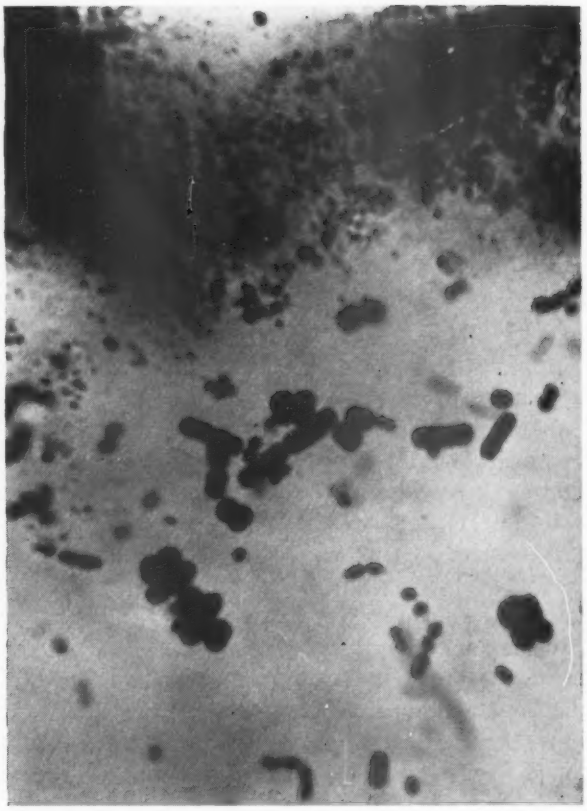

FIG. 4. Cleared smear of exudate from standardized wound of goat. The predominant organisms are cocci, but the biologically significant organism is a gram-positive rod.

are gram-positive aerobes which resemble them morphologically. A report that culture demonstrates the "presence" of clostridia, or that smear shows gram-positive rods is interesting, but not much more. Even more misleading is a pseudoquantitative report that such-and-such an organism is "predominant." In the smear illustrated in Figure 3 the predominant organism is clearly a gram-negative rod; in Figure 4 the predominant organisms are cocci. In both instances the smear is from an animal dying of severe clostridial infection. The significant determination in both cases is not that of "predominance," but the determination, on quantitative study of the smears, confirmed by quantitative plate cultures, that both of these specimens contained Cl. perfringens in concentrations of more than 10 million per ml.

Any surgeon who has examined many wound smears will realize immediately that few of them give so neat an appearance as do those in Figures 3 and 4. These smears have been cleared of blood and debris by a simple and readily available technique [*15*]. By studying stained smears cleared by this method and prepared by a simple quantitative procedure [*16*], we have concluded that it is possible to obtain clinically useful data within a few minutes after a smear is taken. If the quantitative estimate shows 10^7 or more gram-positive rods per ml., the animal usually does at that moment have a serious clostridial infection. We have not found aerobic gram-positive rods (bacilli) to be a source of error on such a quantitative scale, provided the smear is taken from the surface or substance of muscle tissue deep in the wound, and not from pooled superficial exudate.

At the same time the swab is prepared for quantitative estimation on stained smear, a plate of Evan's blood azide egg yolk medium [*6,17*] can be streaked for culture identification. If the streaking is done in a controlled manner, it does not take a whole batch of your plates in order to get a quantitative reading, although this is probably the safer course of action for the study of sporadic cases in clinical practice. In our laboratory investigations we have used

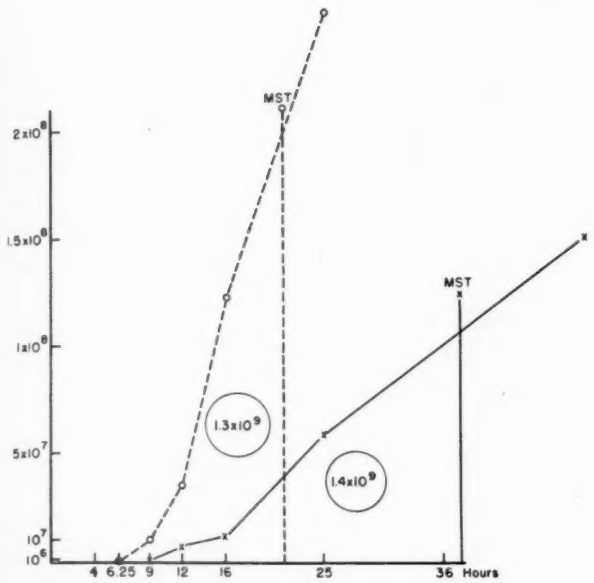

FIG. 5. Cumulative "dose" (circled figures) of gram-positive rods per ml. of wound exudate (direct smear) tolerated by animal up to time of death. Curves of concentration of organisms are mean figures for groups of thirty-six animals each: o - - - - - o = untreated animals; x———————x = animals treated with penicillin, MST = mean survival time.

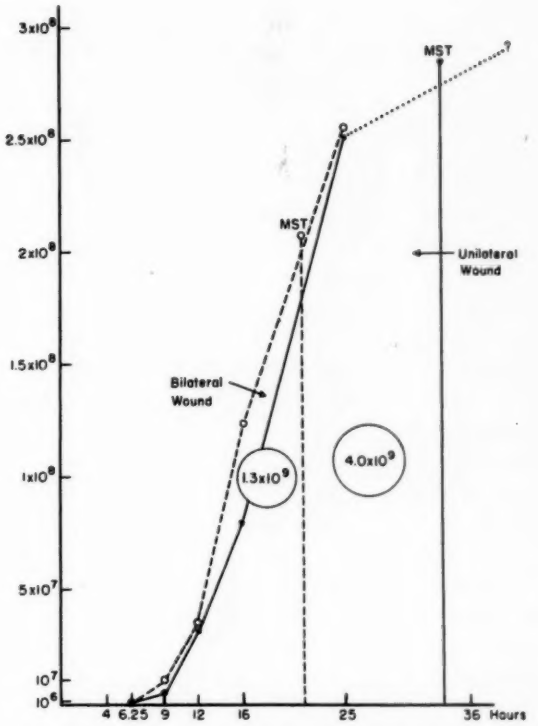

FIG. 6: Cumulative dose (circled figures) of gram-positive rods per ml. of wound exudate (direct smear) tolerated by animal up to time of death: o - - - - - o = untreated animals with bilateral wounds, same data as presented in Figure 5; ●———————● = mean concentration figures for twelve animals with unilateral wounds; ● · · · · · ? = data too limited and too variable to be of significance; MST = mean survival time.

a serial-dilution surface plating method [*16*] that permits quantitative estimations, on a single plate, over a range of six logs: $< 10^3$ to $> 10^{7.5}$. If the concentration of clostridia is high, there is usually sufficient growth to permit presumptive confirmation of the smear estimation in twelve to eighteen hours of incubation.

PROGNOSIS

As indefinite as is the matter of diagnosis, determination of prognosis is even more uncertain. To the intangible processes of clinical judgment which make up the formulation of a prognosis, experience with this preparation adds little except to point up for consideration the question of the mass of tissue involved, or potentially involved by reason of inclusion in the same fascial compartment.

Although our experience is with a standardized wound of a standardized location, we feel that the recent experimental data, and the data from the earlier studies on standardization of the preparation tend to give experimental support to the logically simple assumption that the greater the mass of infected tissue the greater the severity of the disease. As simple as such an assumption is, it seems to have been ignored frequently in practice. A notable exception is the case of the full-thickness burn.

The quantitative data by which it was demonstrated that these animals were dying, at least in part, from clostridial infection, were determinations of the cumulative "dose" of clostridia sustained by the animal up to the time of death [*6*]. In terms of such a dose (organism-hours per ml. of wound exudate), it is evident from Figure *5* that untreated animals, at time of death, have tolerated a mean cumulative dose of a little more than 1×10^9 Cl. perfringens organism-hours per ml. of wound exudate. Animals treated with penicillin live about twice as long, but when the time comes that they too have lived in company with a little more than 1×10^9 perfringens organism-hours per ml., they too die. The base of comparison of the two figures is valid; since the wounds are of exactly comparable size and type, the "per ml." factor is a constant.

If animals are wounded in one leg only, they do not live twice as long, but they do live long enough to have stood in company with approximately twice as great a clostridial dose. (Fig. 6.)

In the earlier standardization studies on the preparation it was found that survival time was influenced only slightly by a 50 per cent increase or a 50 per cent decrease in the size of the explosive charge, but likewise it was noted that changes in the explosive of that order of magnitude produced minimal changes in the gross extent of the wounds. Earlier studies also demonstrated that wounds inflicted by the standard charge on the foreleg involve a smaller mass of muscle, and the animals live approximately twice as long [1].

TREATMENT

Surgery. These studies do not offer data adequate to draw inferences as to the operative surgical treatment of gas gangrene.

Supportive Measures. Recent studies of the preparation have indicated that, in both untreated animals and animals treated with penicillin, there is a good correlation between survival time and the rate of loss of circulating blood volume [9,10]. The decrease in blood volume in these animals is certainly not due entirely or even principally to infection in the wound, but it is worth noting that clinical clostridial infection of an open wound in muscle is characteristically associated with marked exudation of fluid. We have noted a similar phenomenon in most of our animals. In some animals the amount of fluid lost through the wound is enormous; on a few occasions the rate of loss has been measured and losses have been computed which run as high as 2,500 ml. per day. This is certainly a significant proportion of the fluid, protein, and electrolyte reserves of an animal which has a circulating blood volume of only 2,000 to 2,500 ml. The need for careful electrolyte, protein, and fluid replacement may be inferred.

Antibiotics. In man, and in other preparations of experimental clostridial infection, the consensus appears to be that one of the tetracyclines is the antibiotic of choice. We have had relatively little experience with these drugs in our preparation. Principally we use penicillin. It does not give quite so great a prolongation of survival time as does chlortetracycline, for example. Our choice of penicillin has been one of convenience and economy.

We have used penicillin in large doses in some of our animals—as high as 5 gm. (8,000,000 units) per day. When using doses of this order we have studied only the intermittent intravenous route of administration. The results have been disappointing. In general, we have obtained longer mean survival times using only 2.4 gm. per day by intramuscular injection: 1,000,000 units of crystalline penicillin G potassium and 300,000 units of procaine penicillin G aqueous suspension, every eight hours. However, the results have been too variable to support statistical significance of the differences in survival time.

Antitoxin. In theory, the state of antitoxin treatment should be as simple as the statement in Prevot's masterful treatise on the biology of anaerobic infections: "Contre la toxine circulante, seule la serotherapie est efficace" [18]. However, it is evident that there is less and less clinical enthusiasm for antitoxin. Some surgeons have abandoned it altogether, and the United States Army recently dropped it from its standard stock list. This position is understandable. There is actually some considerable doubt that a true toxemia, a circulating clostridial exotoxin, does exist. Ever since the demonstration many decades ago of the production of exotoxins by clostridia *in vitro*, it has freely been assumed that the organisms produced similar toxins *in vivo;* and that toxemia is a major factor in the picture of the clinical disease. There is good evidence to support the proposition that the organism does produce toxin *in vivo*, and that the toxin is responsible in great part for the local and systemic manifestations of the disease. However, there is no convincing demonstration that the toxin *per se* reaches the blood stream, or that the toxin itself is responsible for the "toxemic" picture. There is some evidence to the contrary.

In their original paper on the discovery of an exotoxin of the Welch bacillus, Bull and Pritchett [19] recognized (and dismissed, but did not clearly rule out) the possibility that the systemic manifestations of gas gangrene are pharmacological responses to products formed by the action of the organism on tissue; they described clearly the difference in mode of death after intramuscular injection of toxin as compared to intravenous injection. More recent analyses [20–22] of the clinical picture

have pointedly supported the hypothesis that the primary action of toxin is local, and that the generalized symptoms, and death, are due to secondary products. Such an hypothesis should be intriguing to the surgeon; it makes clostridial "toxemia" relatable to a whole group of shock-like states, from the crush syndrome to fat embolism. It may be, however, that Bull and Pritchett were correct in adopting the theory of a dual action exotoxin, even with respect to the "pure" α-toxin of Cl. perfringens. Although this is generally considered to be a lecithinase (rather than to "contain" a lecithinase), comparative lethality titrations of perfringens and bifermentans toxins of equal lecithinase activity [*23,24*] might be interpreted to indicate that perfringens α-toxin may contain two moieties, one a lecithinase, one a lethal toxin of some other nature.

At any rate, it is my personal opinion that much of the lack of enthusiasm for the clinical effectiveness of gas gangrene antitoxin is due to inefficient usage of currently available antitoxins. The inefficiency would appear to be in several violations of the dictum of Forrest:* "Git thar fustest with the mostest."

Antitoxin is often given relatively late in the course of the disease—too late for it to have an optimum effect. This is not an implication of procrastination, but a forthright recognition of the difficulties inherent in making a really early diagnosis.

It may well be that in clinical use antitoxin is being dispatched by the wrong route or to the wrong place—it does not "git thar." If the primary lethal action of the toxin is destruction of tissue, then intravenous injection of antitoxin is an inefficient procedure. It would appear preferable to inject the antitoxin into the tissue itself. There are few reports of clinical use of antitoxin by local injection [*27,28*]. The suggestion for the local use of antitoxin is not original with us [*29*], but we are unable to find reports of intensive, controlled, experimental comparisons which would settle this issue.

As for the last point in Forrest's dictum—adequate qutanity—our data would tend to support an inference that the customary dosage of antitoxin is woefully small. From the earliest days of arithmetic one can still recall the lesson that it is impossible to subtract one pear from ten apples. Nevertheless, it is possible to make some sort of useful quantitative comparison between dissimilar items, and such a comparison is enlightening with reference to ordinary doses of various types of antitoxins. In diphtheria, a reasonable dose of antitoxin is 20,000 units; in tetanus a reasonable dose is 50,000 units; in gas gangrene a dose of 100,000 units of Cl. perfringens antitoxin is somewhere around the "ordinary" figure. But the quantitative comparison is vitiated because a "unit" is such a variable quantity [*30*]. In terms of protection of experimental animals, 20,000 units of diphtheria antitoxin is about enough to protect 2 million guinea pigs of 250 gm. against a lethal dose of toxin; 50,000 units of tetanus antitoxin is about enough to protect 50 million guinea pigs, of 350 gm.; but 100,000 units of Cl. perfringens is only enough to protect 1 million pigeons! The dosage of gas gangrene antitoxin suffers even more on comparison when one considers the mass of tissue which may be involved. The patient with diphtheria may have only a superficial infection in the pharynx; the patient with tetanus may have an infection limited to 1 gm. of muscle in the base of the thumb; the patient with gas gangrene may have an invasive infection involving ½ kg. of muscle in the calf.

In our experiments on goats, 90,000 units of Cl. perfringens antitoxin, equivalent on a weight basis to about 140,000 units in adult man, is definitely a marginal dose. On intravenous injection it may have a slight effect, but the apparent increase in survival time is so limited that it has not been found to be of statistical significance even after extensive trial. The same amount of antitoxin, injected locally into the wound area in goats otherwise untreated, has produced a suggestively significant increase in survival time ($p < .05$) [*31*]. In penicillin treated animals, in which the clostridial population (and amount of toxin produced) is markedly decreased, the same dose of antitoxin, injected locally, shows a highly significant effect ($p < .001$) in prolonging survival time [*8*]. The marginal nature of this dosage is even more evident when it is realized that the antitoxin was administered (intra-

*Lieutenant General Nathan Bedford Forrest, Confederate States Army. Even as colorful as Forrest was, it is probable [*25*] that frequent passages through print and rhetoric are responsible for the present form of a more prosaic remark, offered casually in explanation of tactical success: "Well, I got there first with the most men" [*26*].

venously, or by infiltration into the hindquarters) immediately before wounding.

It is necessary to hedge the clinical inference with strong words of caution. We have not had access to a sufficient supply of antitoxin to test really large doses by intravenous injection. We would like to try doses of 6,000 to 18,000 units per kg. Our supply of antitoxin has been too limited to determine conclusively whether the effect of injection into the wound area is an effect of local proximity to infection, or simply an effect of intramuscular injection; from the basic time relationships involved [*32*] we prefer the former interpretation. We are certain, however, that the effect is specific to the antitoxin content of the immune serum, and not due to a non-specific effect of injecting large quantities of horse gamma globulin. Parallel control studies, with similar dosage of identically processed slaughter-house horse serum, showed no effect on survival time.

We believe that these data may be worthy of consideration for clinical trial of local injection of antitoxin. If local injection is combined with excisional surgery it should be even more effective, due to the decrease in mass of infected tissue.

Miscellaneous. Earlier studies on the preparation have indicated that significant prolongation of survival time can be obtained by such simple measures as irrigating the wound with water, or by packing the wound with ice [*4*]. As improvisations in disaster, these methods should be clearly useful. For normal clinical use, controlled local hypothermia may be valuable. And in spite of the past disappointments in treatment of local wounds, I personally believe that it is possible to develop a solution or emulsion for local use that would be useful when surgical excision of infected tissue is technically infeasible, or tactically unavailable. Such a solution or emulsion might contain a wetting agent (some of these are known to destroy clostridial toxins), an antibiotic or chemotherapeutic agent (possibly the previously discarded p-(aminomethyl) benzenesulfonamide or a flavine derivative), and chemical counter-toxic agents (such as ethylenediamine tetraacetic acid). It might even be worthwhile to look for the biochemical basis of the favorable action of balsam oil [*33,34*].

Very marked prolongation of survival time can be obtained by interrupting the arterial blood supply to the wound area; the wound remains relatively dry, the organisms proliferate at a much lower rate; and even when the growth does finally reach a peak concentration, the animal tolerates the infection for a much longer period of time [*11*]. These data are consistent with findings from experiments comparing clostridial concentrations in muscle in the wound, with clostridial concentrations in muscle excised at time of wounding, and maintained in the laboratory *in vitro:* at any given time during the experiments (limited to twenty-four hours) the concentration in the excised muscle *in vitro* was approximately 1,000 times lower than in the muscle *in vivo* (in the wound) [*35*].

It is interesting to note that Dr. Henry F. Campbell of Augusta, Georgia, recommended during the Civil War the ligation of major arterial trunks to gangrenous areas [*36,37*]. This recommendation cannot be passed off simply as bizarre and impulsive. Campbell was a scientist of repute, and stood high in the profession of his day. He was noted as an astute clinical observer rather than an experimenter [*38,39*]; he initiated his radical treatment of gangrene as a soberly conceived experiment; and only after clinical experience did he propose it publicly. Campbell's method is extreme treatment, but in light of our experimental data, it may well be useful treatment in extreme circumstances. Although relative ischemia in a wounded area apparently predisposes to gas gangrene, a deliberate and complete ischemia might be lifesaving.

SUMMARY

From reports of experiments involving several thousand standardized experimental wounds in goats, and from detailed studies, in over 300 animals, of the severe clostridial wound infection which is characteristic of the preparation, the following inferences are drawn:

1. The classical clinical picture of gas gangrene may be a poor guide to really early diagnosis of clinically significant clostridial infection.

2. Simple techniques of quantitative bacteriology offer some promise for supporting clinical suspicion, making possible a definitive diagnosis at an earlier stage of the disease and permitting the earlier institution of accepted surgical, antibiotic, and fluid therapy.

3. The customary dosage of clostridial antitoxin is too low.

4. A given dosage of antitoxin may be more effective if injected locally in and around the wound than if injected intravenously.

5. In extreme or unusual circumstances, ligation of the arterial blood supply to the infected area may be a measure of considerable expedient value.

Acknowledgment: I am indebted to Prof. H. H. Cunningham, Elon College, North Carolina, for calling my attention to the work of Dr. Henry F. Campbell; and to Mr. N. J. Anthony, Associate Editor, *Army*, for helping me to track down what Forrest actually did say.

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The Present Status of Dextran As a Plasma Expander

JOHN M. HOWARD, M.D., *Philadelphia, Pennsylvania,* RICHARD V. EBERT, M.D., *Little Rock, Arkansas,* WALTER L. BLOOM, M.D., *Atlanta, Georgia,* AND MARGARET H. SLOAN, M.D., *Washington, D. C.*

THROUGHOUT the past eight years, committees of the Division of Medical Sciences, of the National Research Council have been vitally interested in the development of a plasma volume expander which was effective and safe, yet which could be produced inexpensively, in large quantities, stored in varied climates, and would remain stable under conditions of storage for long periods of time.

In its advisory position to Federal agencies, the National Research Council has always accepted the position that blood and its natural derivatives provide more physiological means of replacement therapy than do synthetic substitutes. Aside from this preference, however, an inexpensive synthetic expander appeared to have an important place in both civilian and military medicine. In civilian hospital practice, the immediate availability of such an expander for instantaneous use while blood is obtained and crossmatched would prove an obvious advantage. The sterility of the expander in regard to the hepatitis virus and its relatively low cost were additional considerations.

After working for several years with the various expanders and studying the problem, the members of the Subcommittees on Shock and Trauma came to the conclusion that the best plasma expander available was dextran. Subsequently, in 1951 the National Research Council recommended to the Federal Government that dextran be stockpiled for use in military or civilian disasters. This recommendation was based on years of study by many investigators in this and other countries, and on its use by many clinical teams. During the course of these studies, several members of the Subcommittees have utilized dextran widely and have come to depend upon its use in their emergency room services. We who used this expander extensively are confident that dextran gives additional time in the resuscitation of the critically injured, during which blood or blood derivatives may be obtained.

NATURE OF DEXTRAN

The term dextran was first used to describe the gums of carbohydrate nature which were formed in the juice of sugar beets and grapes. Later Pasteur demonstrated that dextrans were the result of microbial action [*1*].

Dextran, as produced for use as a plasma volume expander, is a polysaccharide produced by the enzymatic action of a streptococcus, Leuconostoc mesenteroides, on sucrose to form a high molecular weight polymer of glucose. This polymer can be partially hydrolyzed and fractionated to produce an average molecular weight of 75,000.

Dextran is a glucose polymer in which the glucose molecules are joined for the most part by one-six linkages and with varying degrees of branching; the molecular weight of a given dextran preparation is dependent upon the number of glucose molecules which it contains. Since dextran is produced by bacterial action, the industrial preparation of dextran results in the production of molecules of many sizes. Thus a bottle of dextran, as prepared according to American specifications for clinical use contains dextran molecules of various molecular weights. The average molecular weight is 75,000 ± 15,000. (Table 1.) The average of the top 10 per cent is not greater than 200,000. The average of the lowest 10 per cent is not less than 25,000. The determination of the particular molecular weight range which may be

TABLE 1
MOLECULAR WEIGHT OF DEXTRAN AND SERUM PROTEINS

	Approximate Molecular Weight
Serum albumin	68,000
Serum gamma globulin	156,000
Fibrinogen	400,000
Commercial dextran	75,000
Glomerular threshold	45,000

preferable for clinical use has been under continuing investigation.

PHYSIOLOGICAL ACTIVITY

Repeatedly, studies of commercial dextran preparations have demonstrated the colloid osmotic pressure of the dextran molecules, an effect by which dextran in the same way as plasma proteins can maintain the plasma volume. The glomerular membrane has a threshold to inert molecules which permits the passage of those with molecular weights below a level of about 45,000. Such molecules pass through the glomerular membrane rapidly after infusion and are excreted in the urine and therefore contribute little to the plasma volume expanding effect. Molecules in the range of 60,000 to 200,000 circulate in the blood stream for periods up to twenty-four hours and are then either broken down and excreted or metabolized. The large molecules are probably picked up by the reticuloendothelial cells and are eventually metabolized, very little being stored for longer than two weeks.

That dextran results in a temporary increase in blood volume is unquestionable. Its administration produces a hemodilution with a fall in hematocrit and a decrease in the concentration of plasma proteins. Serial studies of blood volume and of plasma dextran concentration reveal that the blood volume increment, reaching its peak shortly after administration, gradually subsides and that at the end of six hours over 50 percent of the administered dextran remains in the circulation.

SIDE EFFECTS OF DEXTRAN

During the early developmental days, periods when different types of dextran were being evaluated, observations were made on some dextrans indicating a high incidence of allergic reactions. Today, with dextran made according to National Research Council specifications, this is seldom a clinical problem. During the past few years, investigators have demonstrated an increased bleeding time by the ear lobe test following the administration of large amounts of dextran to normovolemic people. Although this is a valid observation, it has not produced increased bleeding as a surgical problem. In the recommended range of dosage, thousands of patients have received dextran in quantities of 1,000 to 2,000 ml. each. Among this large group in whom dextran has been used therapeutically, resultant bleeding has not proved a clinical problem.

CLINICAL EXPERIENCES

Many reports have been written concerning the occasional rare reactions to the administration of dextran; few have been written to describe the present day usefulness of this expander [2]. Most clinicians who have used dextran and found it useful have not analyzed and compiled their experience for publication. Indeed, thousands of liters are being used annually, many surgeons having come to lean upon dextran as an extremely valuable crutch in providing emergency care. Its place has been found to be that of a resuscitative agent for immediate use while blood or blood derivatives are being obtained. *Its place is in the emergency room and operating room, not on the wards or in the pharmacy or storeroom.*

In the urban hospitals, where blood banks are active, dextran has proved of value in the emergency room while blood is being obtained. In smaller community hospitals where donor lists are utilized rather than banked blood, dextran has a more prolonged range of usefulness. The practitioner who is isolated from institutional facilities should find an even wider use for dextran as he institutes emergency care of his scattered patients.

MILITARY UTILIZATION

Following its widespread civilian utilization, dextran was introduced into Korea for the treatment of battle casualties in the forward combat areas. Initially its use was restricted to those casualties who could be studied by blood volume and metabolic studies. When the severely injured casualties were found to respond to dextran to a degree comparable to civilian experience, the utilization of dextran

TABLE II
DEXTRAN STOCKPILES
(APPROXIMATE)

	Units of Dextran (500 ml.)
Federal Civil Defense Administration.....	3,475,000
Department of Defense.....	1,400,000

was increased. Finally, because of the incidence of hepatitis following administration of pooled plasma, the latter was withdrawn from the combat theater. Only dextran and albumin were utilized thereafter in those areas in which blood was not immediately available. One group supervised the administration of 4,000 units of dextran within a period of a few months [3]. The results of its clinical use under these conditions were gratifying.

FEDERAL STOCKPILE

Based on many years of study, the National Research Council recommended to the Department of Defense and to the Federal Civil Defense Administration that dextran be included in the national stockpile. Currently, it is the only expander recommended by the National Research Council for additional stockpiling. This recommendation is based not only on its usefulness but on the fact that in contradistinction to polyvinylpyrrolidone (P.V.P.), dextran is metabolized rather than stored. At present, 3,475,000 units (500 ml. each) have been stockpiled by the Federal Civil Defense Administration and a smaller quantity by the Department of Defense. (Table II.) The stockpile has been gradually accumulated over a period of years. The oldest solution has been in stockpile since 1952, six years. To date, it appears to tolerate the prolonged period of storage quite well. The occasional slight precipitation of dextran from solution can be counteracted by warming the bottle to 90°C. for one hour or reautoclaving.

COST

Dextran is inexpensive now that the developmental stage has passed. In dry bulk form, dextran is sold by the manufacturers at $13.00 a pound. Civilian hospitals pay $6.50 per unit. As compared with blood plasma and albumin, this is relatively inexpensive. (Figs. 1 and 2.)

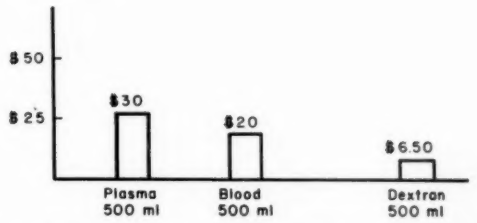

FIG. 1. Comparative costs to hospital (approximate).

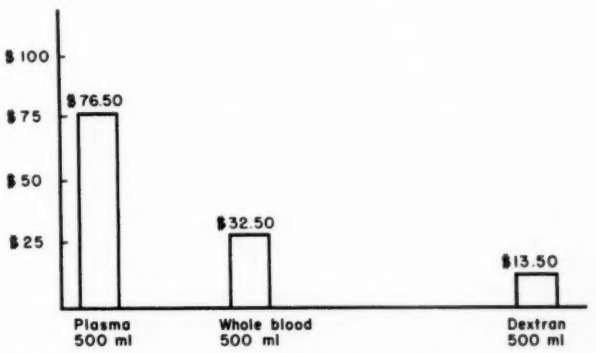

FIG. 2. Comparative costs to patients (approximate).

THE CURRENT PROBLEM

Currently, stockpiling of dextran has come to a pause and future production appears to depend upon civilian utilization. In 1957, total civilian use amounted to less than 150,000 units. At present dextran is produced in several other countries but only one commercial company is in production in the United States. Its maximum capacity is 130,000 500 cc. units per month but its current production volume is only 65,000 units per month. (Table III.) Should the demand not justify its continued commercial existence and the last surviving dextran plant in the United States close, a delay of eight months in resuming production might be anticipated in case of a national emergency during which the only sources of additional dextran would be Sweden or England. This is a problem of which the profession should be aware.

TABLE III
DEXTRAN—THE CURRENT PROBLEM (1957)

	Units of Dextran
Total civilian utilization (United States).....	150,000 (yearly)
Current production volume of only factory in United States.....	65,000 (monthly)

The only other information is the following excerpt from the Washington Report on the Medical Sciences, August, 18, 1958:*

CIVIL DEFENSE EQUIPMENT

"As approved by the Senate, the supplemental funds bill also includes $4 million to go to the Office of Defense and Civilian Mobilization for purchase of protective devices and equipment. These are intended for loan or grant to the states. Of the total allowed, $500,000 is earmarked for procurement of dextran to go into the blood expander stockpile.

" 'The [Senate] committee understands,' said its report, 'that this new procurement will not add to the total units presently available for transfusions, but is necessary to maintain the medical stockpile at current levels which would otherwise be reduced because of shrinkage resulting from the re-working of blood plasma in the stockpile in order to restore its original effectiveness.' "

* Since this was written, the Office of Civil and Defense Mobilization has agreed to the current purchase of $250,000.00 worth of dextran for this purpose.

SUMMARY

Many years and a heavy investment have gone into the development of an acceptable plasma volume expander. Dextran has been developed, has now proved inexpensive and of great value in emergency treatment. Few emergency rooms can provide optimal therapy unless such a product is available for immediate utilization in the treatment of hypovolemic shock.

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Pasteurized Human Plasma

MELVIN A. CASBERG, M.D.,* T. G. BLOCKER, JR., M.D., WILLIAM C. LEVIN, M.D. AND E. FRANK DUNTON, M.D., *Galveston, Texas*

From The University of Texas, Main Campus, Austin, Texas; and the Department of Surgery (Plastic and Maxillofacial Surgery Division), the Department of Internal Medicine, and the Hematology Research Laboratory, The University of Texas Medical Branch, Galveston, Texas.

LIVING as we are in a period which historians of the future may well designate as the "Era of Cold War," we face the constant potential of mass injury to the civilian as well as the military population. Although the basic principles of medicine are universal in their relationship to the therapy of trauma, nevertheless the problems of major catastrophes frequently necessitate certain therapeutic modifications to conform with such uncontrollable variables as the numerical mass of those injured, the environment and pattern of evacuation of the injured, or the availability and qualifications of medical personnel.

Unfortunately, medical lessons, learned at a considerable cost in the grim classroom of combat, have been forgotten all too soon and of necessity have been restudied under great difficulty and at the sacrifice of human lives. Basic factors related to the intelligent care of mass casualties should be kept fresh in the minds of the medical profession and re-evaluated from time to time in the light of further experience and the more recent contributions of research.

In spite of the seemingly insurmountable problems complicating the global nature of the medical responsibilities of our Armed Forces, American medicine may well be proud of her success in this saga of human salvage, for never before in the history of warfare has a seriously wounded man faced such high odds in favor of survival. In World War I, of every 100 men wounded in action (that is, those who survived initial injury long enough to receive any emergency medical care), eight died. By comparison, during the Korean conflict there was a mortality rate of only two of every 100 men wounded.

Among the major factors contributing to the improved chances of survival on the part of the seriously injured is that of the replacement of circulating blood volume. In any future mass catastrophe, the availability of qualitatively and quantitatively adequate supplies of blood, blood derivatives and plasma expanders will constitute one of the critical factors in the salvage of lives.

In a recent report [1] on the need for blood in the event of an atomic attack on five major cities in the State of California, with over 1 million surviving casualties, it was estimated that with three eight-hour shifts per twenty-four hours and with a different team used in each shift, there would be required approximately eighty-four teams (8,820 personnel) to draw and process the necessary 67,647 units of blood per day. In the light of the fact that whole blood is outdated in three weeks and that the stockpile in our blood banks (if not destroyed in the catastrophe) would be totally inadequate quantitatively, the only real source of blood in such an emergency would be the "walking bloodbank."

Under the stark realism of these facts only one conclusion emerges, and that is the utter inadequacy of the estimated available supply of whole blood during the first days of a national catastrophe. This leaves the brunt of the initial burden, in the support of the collective failing circulation of trauma, on the blood derivatives and plasma expanders.

BLOOD, BLOOD DERIVATIVES AND PLASMA EXPANDERS

No surgeon familiar with the clinical care of the patient in hemorrhagic shock will argue the

* Present address: Austin, Texas.

fact that in such instances there is no substitute for whole blood. For under these circumstances the emergent need is far more than that of an adequate volume of circulating fluids and must relate also to the oxygen carrying capacity of the red blood cells.

In the absence of whole blood, however, it is the consensus of surgeons familiar with the surgery of trauma, that plasma is the next best replacement therapy for hemorrhagic shock. Plasma, besides its colloid osmotic or oncotic effect, has numerous other functions ranging from that of protein nutrition to the establishment of defense mechanisms against infection. Although plasma fractions, such as serum albumin, have a place in the therapeutic armamentarium for the care of injury, these fractions are not the equivalent of whole plasma.

Aside from hemorrhagic shock (in which case all are agreed that whole blood is the treatment of choice), there are other types of traumatic shock, such as those resulting from crushing injuries and severe burns, which, in certain phases of their course, respond equally well or even better to the use of plasma. Further technical advantages of plasma over whole blood, particularly significant in the emergency environment of large scale catastrophe, are that no typing or cross-matching is required prior to its administration and that it lends itself to long term storage. Although these statements would seem to be obvious and self-evident facts to the majority of the medical profession of today, it is disconcerting to hear discussions and read papers which, in the face of problems related to the viral contamination of pooled plasma, would appear to relegate this important tool in the treatment of trauma to a category of obsolescence.

During the Korean conflict, data were accumulated proving that lyophilized pooled plasma served as an effective medium for the transportation and dissemination of the serum hepatitis virus. Under these circumstances the incidence of serum hepatitis was reported as high as 20 per cent [2]. As a result of this distressing situation the Department of Defense called back the widely distributed stockpiles of plasma and, with the approval of the National Research Council, substituted synthetic plasma expanders. It was understood that these expanders, dextran and polyvinylpyrrolidone, were not valid substitutes for blood or plasma and were temporary stopgap measures until the problem of serum hepatitis virus could be solved. More than five years have transpired since this action.

Dextran, which has been considered to be the safer of the two approved synthetic expanders, is inferior to pooled plasma for a number of reasons, among them the fact that hemorrhagic manifestations with a prolonged bleeding time (occasionally to a dangerous extent) have been reported. Anaphylactoid and pyrogenic reactions as well as "sludging" of blood, and other untoward clinical reactions have occurred following use of these synthetic compounds. The possible prolonged retention of these expanders in the body tissues has given concern, particularly in the light of studies [3–5] in relation to the possible carcinogenic effect of polyvinylpyrrolidone.

PASTEURIZED HUMAN PLASMA

There have been two major areas of investigation in the attempted solution of the problem of the serum hepatitis virus contamination of pooled plasma. One of these has related to the fractionation of plasma proteins and has resulted in the collection of a virus free albumin. The other is involved in the search for a means of treating whole plasma in a manner which will eliminate the virus of serum hepatitis without altering the essential biological properties of the constituent plasma fractions.

Although the fractionation program has been successful to the extent that a virus-free oncotically effective protein fraction is now available, there are certain serious drawbacks to the dependence on this product alone for stockpiling toward future needs in the event of a national emergency. In the first place, serum albumin is not a substitute for whole plasma, and in the second place the production of this fraction is not only much more expensive and time consuming than the processing of plasma, but also has a lower yield. These factors are quite significant in the light of the extensive stockpiling needs of our nation.

Two apparently successful techniques have been developed as means of plasma sterilization, namely, the storage of liquid plasma at room or higher temperatures for six months [2–6] and the pasteurization of pooled plasma [7]. The former technique, although apparently effective in its purpose of eliminating an infective contaminant without significant biological altera-

tion of the plasma constituents, presents certain serious time problems in the logistics of stockpiling and processing. The latter method of pasteurization lends itself admirably to the needs inherent in an adequate stockpiling for national emergency purposes.

Gellis and associates [8] reported that heating at 60°C. for ten hours inactivated the virus of serum hepatitis in a mixture containing 40 ml. of 25 per cent human serum albumin and 10 ml. of plasma known to be icterogenic. In view of this study and other supporting evidence as outlined in the clinical trials to be described later in this presentation, it would appear to be safe to assume that pasteurization as just described removes the hazards of the virus of serum hepatitis.

Certain changes, particularly in the alpha$_1$ and beta fractions of the globulin component, have been observed in the electrophoretic patterns of plasma treated by pasteurization. Parenthetically, these changes are quite similar, qualitatively and quantitatively, to those observed in the protein patterns of plasma stored for six months. Perkins and associates [9] have demonstrated in their clinical studies that: the plasma volumes obtained using labeled human serum albumin, heated globulins and unheated globulins were in fairly close agreement; that, although their disappearance rates are approximately the same, heated globulins appear to equilibrate at a lower level than unheated globulins, suggesting that about 30 per cent of the heated globulins are metabolized much more rapidly than the unheated globulins; and the globulins from heated plasma persist in the serum after intravenous administration for a sufficient time to be useful as globulins for plasma volume expansion.

CLINICAL TRIALS*

In the fluid form the pasteurized plasma used in these trials is clear and does not form precipitates either upon standing or agitation. This is important for two reasons: first, ordinary plasma becomes cloudy and forms precipitates which cannot easily be distinguished from the growth of bacteria; and second, even with the use of a filter in the administration of ordinary plasma, it is possible for particles to enter the circulation of the recipient. This pasteurized plasma, which remains clear, avoids both of these objections. In the dried form, in contrast to ordinary plasma, this stabilized and heat-treated plasma reconstitutes into a clear liquid form quickly, completely and with ease.

Under the direction of Frederick J. Moore, Professor of Experimental Medicine, University of Southern California, laboratory and clinical tests on this heat-treated plasma were carried out during 1956 and 1957.* The results of these investigations demonstrated that the plasma retained an acceptable electrophoretic (Tiselius) pattern after heat treatment and resisted further change when stored in the fluid state for two years. Furthermore, it was observed that after long storage the pasteurized plasma demonstrated a more "normal" electrophoretic pattern than did unheated plasma stored over a similar period of time. Schultz-Dale tests performed by Dr. Irving Gordon on the serum of eleven patients who had received the heat-treated plasma were negative, indicating no alteration in the antigenicity of the recipients' proteins. At the request of Dr. Moore, the Division of Biological Standards of the National Institutes of Health in May, 1957, tested this plasma for its comparative oncotic ability, and reported that the osmotic effect attributable to the protein of the heat-treated plasma was slightly greater than that of the standard 5 per cent albumin.

In 1956 Dr. Moore supervised clinical trials of the pasteurized plasma, in most part at the Los Angeles County Hospital, in which eighty-four patients received 130 units. Twenty-two of the readministrations were carried out after an interval of one month. In the latter there were no reactions. Two patients experienced pain in the chest; both had advanced pulmonary tuberculosis and were receiving antimicrobial therapy. Two complained of "chilly" feelings without objective evidence, and repeat infusions did not produce a similar effect. One patient had an elevation of temperature to

* The plasma used in all of these clinical trials was supplied by U. S. Pharmaceutical, Inc. and prepared in accordance with the regulations of the Division of Biological Standards of the National Institutes of Health. In additional preparation to the aforementioned, three steps were taken by the manufacturers to stabilize the product and inactivate the potential viral contaminant: defibrination by freeze-thaw and filtration; addition of invert sugar; and heating to 60°C. for ten hours.

* Unpublished but recorded and on file with the Division of Biological Standards of the National Institutes of Health and the National Research Council.

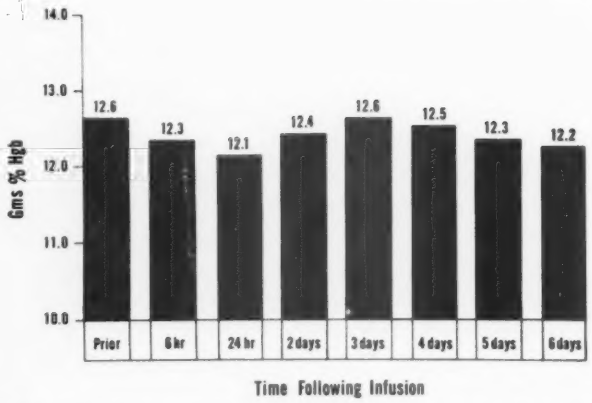

FIG. 1. Mean hemoglobin levels following infusion of 500 ml. of pasteurized human plasma.

100.6°F. six hours after infusion lasting a few hours but without other objective symptoms.

In the light of the promising results obtained by Dr. Moore and challenged by an obviously inadequate national stockpile of blood and blood derivatives for major emergencies, pasteurized human plasma was given further exacting tests and trials at the Medical Branch of The University of Texas. Dr. William C. Levin, Director of the Hematology Research Laboratory, organized and directed the project under the general supervision of Dr. Truman G. Blocker, Jr., Chief of Plastic and Maxillofacial Surgery and Dr. Melvin A. Casberg, Vice-President for Medical Affairs, The University of Texas, and with the assistance of Dr. E. Frank Dunton, resident in plastic surgery.

Thirty hospitalized* patients with varied diagnoses each received 500 ml.† of liquid pasteurized plasma intravenously. There was a deliberate selection of seven patients who had previously experienced hypersensitivity to foods or drugs. In no instance did any of the selected patients present objective evidence of congestive heart failure, renal disease or blood volume disturbance.

The protocol of clinical and laboratory procedures undertaken before, during and at selected intervals following plasma infusion included temperature, pulse, respiratory rate, blood pressure, hemoglobin determination, total leukocyte count, hematocrit, prothrombin time, bleeding time and urinalysis. Prothrombin and bleeding times were carried out over two days. Each administration of plasma was followed with meticulous care, for the most part under the direct personal observation of Dr. Dunton. Not only did this personal supervision relate to the period of actual infusion but continued at hourly intervals for twelve hours, and at daily intervals for seven days afterwards. In twelve of these patients, plasma and blood volumes were determined before the infusion and at one, six, and twenty-four hours thereafter by a standard technique using human serum albumin labeled with I^{131}. Total serum proteins were measured quantitatively and by paper electrophoresis in seven of the patients before the administration of plasma and at intervals of one, six, and twenty-four hours thereafter. A Spinco Analytrol® was used for the quantitative measurement of the paper strips.

Similar observations to those described above were made in five patients receiving a second infusion of plasma three to four weeks following the first.

* The University of Texas, John Sealy Hospital.

† The 500 ml. volume per cent includes approximately 80 ml. of anticoagulant plus 5 per cent by volume of invert sugar.

RESULTS

Thirty patients have received thirty-five infusions of plasma. In the five patients receiving a second infusion, the time lapse was from three to four weeks. To date all of these patients have been observed over a period of time varying from a maximum of nine months to a minimum of five months. There has been no overt evidence of hepatic disease in any patient and no reactions definitely attributable to the plasma were observed in any instance—this in spite of the fact that seven recipients had given histories of allergic sensitivity to foods, inhalants and medications.

In one patient with a history of multiple allergies edema of the hands developed twenty-four hours following the second infusion of plasma. An identical reaction was reproduced in this same patient eight days later by the dermal application of calamine lotion, which, incidentally, had been used at the time of the second infusion. Three weeks following the second infusion and again six months later a skin test was performed using plasma from the same lot and no reaction was observed at either time. In view of these findings it can be assumed that edema of the hands was not related to the administration of plasma. A female patient, inadvertently and for a brief interval, received the plasma very rapidly and complained of a lightheadedness which disappeared as the rate of flow was reduced. The entire 500 ml. of

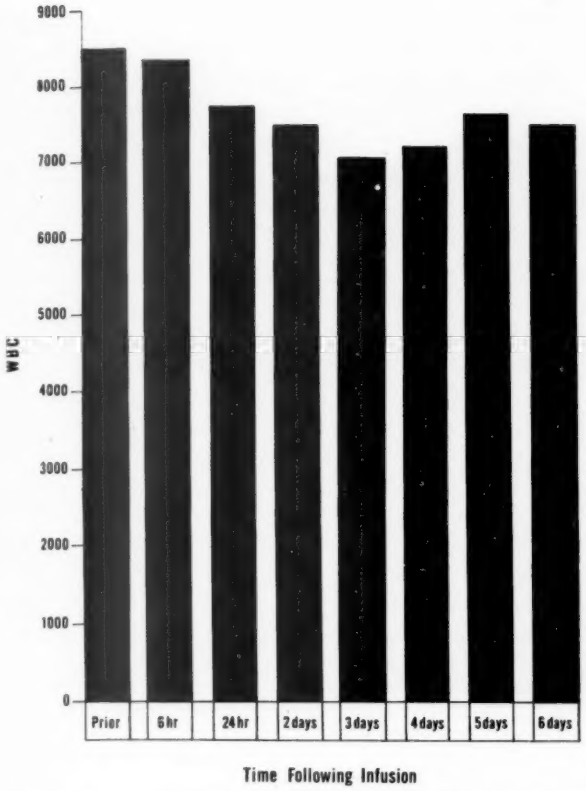

FIG. 2. Mean white blood cell levels following infusion of 500 ml. of pasteurized human plasma.

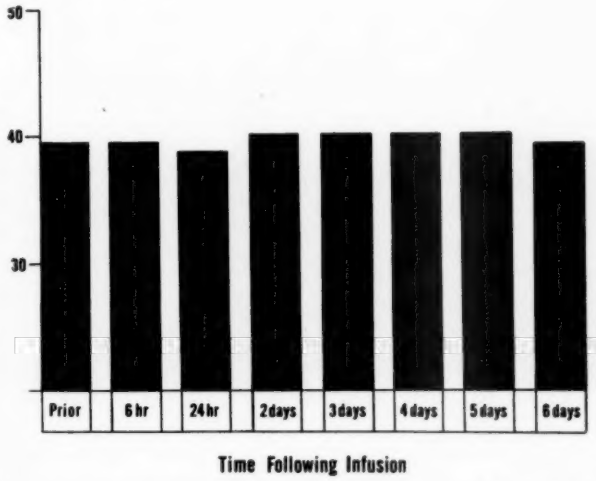

FIG. 3. Mean hematocrit levels following infusion of 500 ml. of pasteurized human plasma.

plasma was infused in this patient without further symptoms. With this exception, none of the patients complained of any subjective symptoms during or following the administration of plasma. The pulse rate, blood pressure and temperature of the recipients presented no significant changes related to plasma administration.

Figures 1, 2 and 3 summarize graphically the hemoglobin, leukocyte and hematocrit values of the plasma recipients. These reveal no significant changes in the peripheral blood picture.

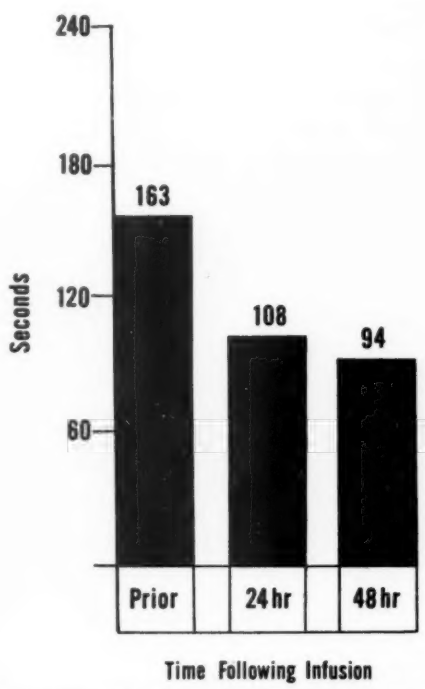

FIG. 4A. Mean bleeding times following infusion of 500 ml. of pasteurized human plasma.

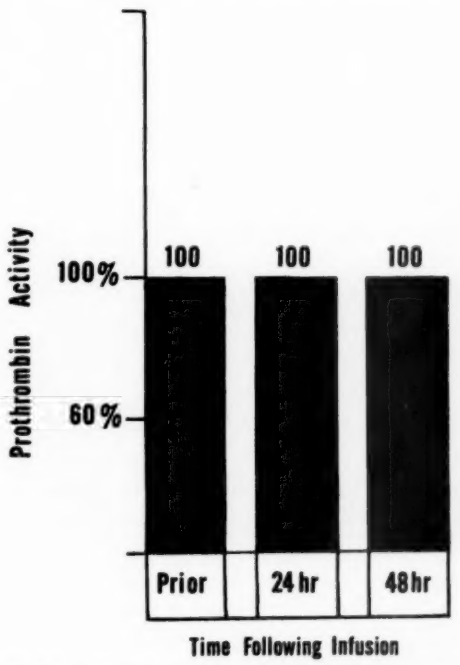

FIG. 4B. Mean prothrombin activity following infusion of 500 ml. of pasteurized human plasma.

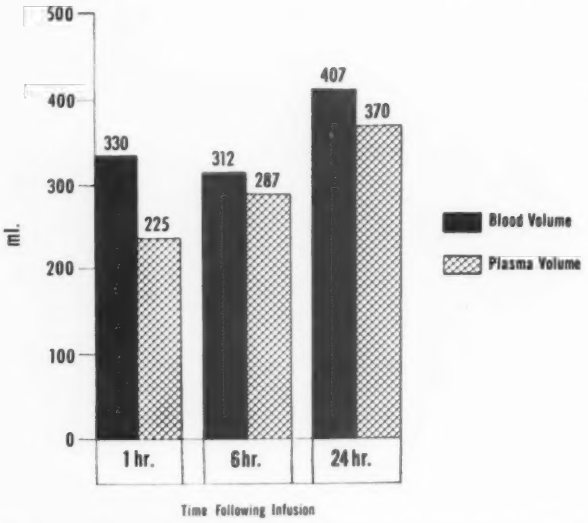

FIG. 5. Mean increases in plasma volume and blood volume following infusion of 500 ml. of pasteurized human plasma.

Time	Alb	alpha$_1$	alpha$_2$	beta	gamma
Prior	40.1	6.0	14.9	12.3	26.5
1 hr	42.1	5.5	14.5	12.6	26.8
6 hr	40.7	5.9	11.2	13.0	27.1
24 hr	39.0	6.0	14.2	14.4	33.0

FIG. 6. Mean electrophoretic values following infusion of 500 ml. of pasteurized human plasma.

Urinalysis following plasma infusion demonstrated no abnormalities that had not existed prior to the experiment. Not only did the prothrombin activity (one-stage) and the bleeding time of the patients remain substantially unaltered following the administration of plasma, as observed in Figures 4A and B, but also there were no hemorrhagic manifestations noted.

Figure 5 presents the plasma volume and total blood volume determinations in twelve patients. It will be noted that there was an average increase in plasma volume of 225 ml. and an average increase in blood volume of 330 ml., one hour following the plasma infusion. At six hours the increase was 287 ml. and 312 ml. respectively; and twenty-four hours following the administration of plasma the average increase of plasma volume was 370 ml. and blood volume 407 ml. These results would support the immediate and prolonged oncotic effectiveness of pasteurized human plasma.

The mean electrophoretic values of the serum protein fractions of recipients determined prior to, and at one, six and twenty-four hours following infusion, are presented in Figure 6. These data show no statistically significant alterations of the protein fractions in the serums of recipients, following the administration of heat-treated plasma.

COMMENTS AND SUMMARY

A carefully planned and closely supervised clinical trial of pasteurized human plasma has been carried out in thirty patients. The protocol established for this experiment was sufficiently inclusive to substantiate the accumulating evidence of the oncotic effectiveness and safety of this heat-treated blood derivative. These results are further supported by the previous clinical experience* with the administration of this pasteurized plasma to eighty-four patients.

A realistic appraisal of our nation's stockpile of blood and blood derivatives for use in the event of a national emergency, will demonstrate a fearful inadequacy. In great part, this inadequacy is directly related to the potential of viral infectivity inherent in the standard source and stock of pooled human plasma. The results of the clinical trials presented in this paper have demonstrated further the effectiveness of the pasteurization of human plasma (heated to 60°C. for ten hours) in the inactivation of the virus of serum hepatitis. Furthermore, evidence accumulated in this research effort would indicate that the pasteurization of plasma does not alter the serum protein sufficiently, either to affect its oncotic effect or to cause unfavorable physiological reactions in the recipient.

In the treatment of traumatic shock, plasma fractions cannot be equated to whole plasma. Furthermore, the process of serum protein fractionation is not only faced with a problem of low yield but also that of a high cost of production. These factors are significant in the consideration of stockpiling.

* Carried out under the direction of Dr. Frederick J. Moore, Professor of Experimental Medicine, The University of Southern California.

Under these terms of reference, two avenues of whole plasma "sterilization" are available for further consideration: the so-called shelf storage method and the pasteurization technique. The products at the completion of these two processes appear to be quite similar. The minimal changes in the protein fractions are closely comparable as determined by electrophoretic studies. The shelf-storage method, however, presents certain logistic problems related to time and storage.

As a matter of National Defense, the inadequacy of our blood derivative stockpile for the care of mass casualties should be cause for deep concern on the part of every American surgeon.

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Follow-up Medical Survey of the Texas City Disaster

T. G. Blocker, Jr., M.D., Virginia Blocker, M.D., Col. J. E. Graham, M.C.* and Herbert Jacobson, M.D., *Galveston, Texas*

From the University of Texas—Medical Branch, Galveston, Texas.

The Texas City disaster of April 16, 1947, resulted from a tremendous explosion of bags of ammonium nitrate fertilizer on board a French ship, the "Grandcamp," at docks adjacent to the Monsanto Chemical Plant, the Texas City Terminal Railway installations, and a number of other industries in the immediate area, all of which were completely destroyed by the combined effects of blast and fire, with millions of dollars of property damage. In round numbers, 560 persons were killed and approximately 3,500 were injured within a mile radius of the explosion center, although the majority of severe injuries occurred within a 2,000 foot zone. Heavy population of the area resulted not only from industrial workers but also from a large number of sightseers, including school children, who had gathered to watch the activities of volunteer firemen during the hour preceding the detonation of an estimated half of the 2,300 tons of ammonium nitrate cargo and the complete disintegration of the ship.

A second similar explosion of equal force occurred sixteen hours later in a freighter undergoing repairs at the next pier, the "High Flier," after attempts to tow it out to sea had to be abandoned. Because the entire Texas City area had been evacuated except for firemen and volunteer workers, there were fortunately only a few casualties from the April 17th explosion.

The exact mechanism of detonation of ammonium nitrate by fire has not been determined. Nevertheless, a number of similar explosions have occurred previously from this material, the most comparable one being in Oppau, Germany, in 1921, in which dynamiting of caked fertilizer resulted in 500 deaths and considerable property damage [1].

The Texas City Disaster Claims Act

After the disaster about 300 court actions were instituted against the United States in the names of approximately 8,500 claimants under the Federal Tort Claims Act for death, personal injury and property damage. The suits were consolidated with the approval of the United States District Court for the Southern District of Texas under one civil action entitled *Elizabeth Dalehite et al. vs. United States*. After a trial of the issues the district judge, sitting without a jury, found negligence on the part of the Government and rendered judgment in favor of the plaintiffs, ruling that the fertilizer was an inherently dangerous product and that the United States was negligent in connection with its manufacture and handling.

On appeal, the Court of Appeals for the Fifth Circuit unanimously reversed this decision, and it was upheld by the Supreme Court on the basis that the actions of the Government and its employees were performed in the exercise of a "discretionary function" and that the Federal Tort Claims Act exempted the Government from tort liability in such a case. After six years of litigation the plaintiffs turned to Congress for legislative relief.

The Texas City Disaster Act,† which was finally approved on August 12, 1955, recognized compassionate responsibility without assumption of any legal liability on the part of the Government for the disaster. The Act directed the Secretary of the Army or his designees to investigate and settle disaster

† P. L. 378, 84th Congress. 69 State. 707.

* Present address: Letterman General Hospital, Presidio of San Francisco, California.

claims within twelve months from the time of filing, with February 9, 1957, set as the deadline for presentation of claims.

Awards were limited to $25,000 for death, $25,000 for personal injury and $25,000 for property damage, with the provision that any insurance or other payments, except life insurance, which had previously been made with respect to the claims should be deducted in computing the quantum. Attorney fees from the awards were limited to 10 per cent, and payments to underwriters and insurance companies for property damage were ruled out. Another limitation restricted claims to those which had been part of a civil action filed in a United States District Court prior to April 25, 1950, except for "good cause and by reason of infancy, insanity, or other legal action."

The Chief, Claims Division, Office of the Judge Advocate General, was subsequently designated as the responsible officer for processing claims submitted in accordance with Public Law 378, with awards for compensation to be determined by the practice and statutes of the State of Texas. On January 11, 1956, the Judge Advocate General requested that the Surgeon General take the necessary action to insure the availability of adequate facilities and professional and technical personnel for the purpose of furnishing medical opinions and such physical examinations as were deemed advisable to obtain an impartial appraisal of the extent of personal injuries of the claimants under the Texas City Disaster Claims Act so that the claims might be processed within the time limit imposed by law. In accordance with this request, the Surgeon General established a provisional unit on March 5, 1956, at Galveston, Texas, to furnish and/or administer the support requested by the Judge Advocate General. It was composed of personnel on temporary duty from their assigned positions and contained an authorized strength of four Medical Corps officers,* with one Medical Service Corps officer, and two Army Nurse Corps officers. Headquarters were established at the John Sealy Hospital by cooperative agreement with the University of Texas Medical Branch.

The original estimate of 900 claimants to be examined was used as the basis to formulate the plan of operation. Since 150 of the persons involved lived at considerable distance from Galveston, they were referred to a military medical facility, Public Health Hospital or Veterans Administration unit near their homes for examination as "Designees of the Secretary of the Army." Brief clinical abstracts were furnished and request was made for the following information: (1) descriptive statement, including a summary of the injured party's history and complaints; (2) diagnosis; (3) indication of disability, if any, as temporary or permanent, with the percentage; (4) evaluation of the past and future physical and mental pain and suffering involved, if any, as slight, moderate, severe or extreme, with a statement explanatory of the evaluation; (5) estimate of future medical expense, if any; and (6) opinion as to the causal relationship, if any, between the Texas City disaster and the injuries alleged.

Of the claimants who resided within a 100 mile radius of Galveston, approximately 70 per cent were processed by the group of Army examiners and the remainder (208) by referral under arrangements with the Galveston County Medical Society to a designated panel of practitioners, who conducted physical examinations according to an established arrangement for fees and ordered specialized consultation and laboratory work and x-rays as indicated.

Upon receipt of completed examination reports, the individual Texas City claim files were forwarded from the Branch Office of the Judge Advocate General. Medical and other pertinent data were reviewed, and the individual was medically boarded, with the completed file returned to the Judge Advocate staff for final claim settlement. Except for a small group of patients, all work of the Army examiners was completed in three and a half months, at which time the personnel of the Branch Office of the Surgeon General on temporary duty returned to their permanent assignments.

A total of almost $17,000,000 has been awarded to the Texas City disaster claimants for deaths, personal injury and property damage in approximately 1,400 awards, according to an unofficial account [2]. Meanwhile, through the cooperation of the Surgeon General and the Judge Advocate General, records of the physical examination data on 846 patients have been made available for use in a follow-up medical survey. Of these, forty-two without valid claims have been discarded, leaving a

* Col. J. E. Graham, M.C., Commanding; Col. R. P. Hughes, M.C., Capt. R. L. Steele, M.C., and Capt. J. E. Davis, M.C.

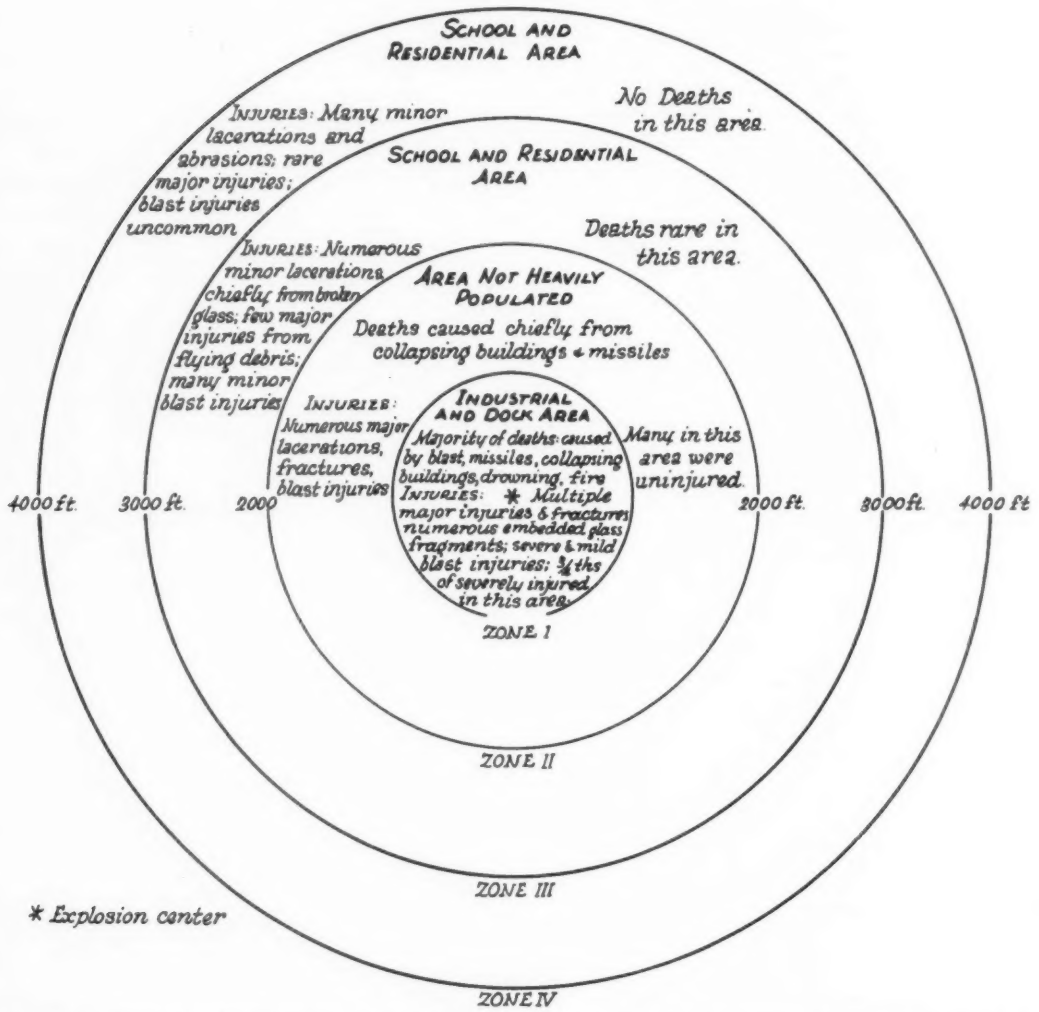
SCHOOL AND RESIDENTIAL AREA
No Deaths in this area.
INJURIES: Many minor lacerations and abrasions; rare major injuries; blast injuries uncommon
SCHOOL AND RESIDENTIAL AREA
Deaths rare in this area.
INJURIES: Numerous minor lacerations, chiefly from broken glass; few major injuries from flying debris; many minor blast injuries
AREA NOT HEAVILY POPULATED
Deaths caused chiefly from collapsing buildings & missiles
INJURIES: Numerous major lacerations, fractures, blast injuries
INDUSTRIAL AND DOCK AREA
Majority of deaths caused by blast, missiles, collapsing buildings, drowning, fire
Many in this area were uninjured.
INJURIES: * Multiple major injuries & fractures; numerous embedded glass fragments; severe & mild blast injuries; ¾ths of severely injured in this area.
4000 ft.
3000 ft.
2000
2000 ft.
3000 ft.
4000 ft
ZONE I
ZONE II
ZONE III
* Explosion center
ZONE IV

FIG. 1. Types of injuries by zones within 4,000 feet of the explosion center. (FROM: BLOCKER, V. Texas City disaster; pattern of injury in 3,000 casualties. *Texas Rep. Biol. & Med.*, 7: 22, 1949.)

total of 804 for study and comparison with records made nine years previously in a survey of 3,000 casualties [3].

ORIGINAL SURVEY, 1947

The original survey included in round numbers 600 who were listed as killed or missing or who died later in hospitals; 1,000 injured, whose location at the time of the blast could be ascertained; an estimated 600 of the 1,400 school children in the area with trivial lacerations; and 800 others injured but not located. Statistics were collected from official records, from direct interviews and by questionnaire. The pattern of injury was studied according to distance from the blast center in four 1,000 foot zones. (Fig. 1.) Detailed analysis of hospital records was carried out, particularly at the University of Texas Medical Branch. The most characteristic findings are shown in Table 1.

Almost all the persons killed and about 600 of the seriously injured were within a radius of 1,000 feet from the explosion. Less than fifty deaths occurred among patients who were admitted to hospitals. Death was attributed to combined effects of blast, dismemberment

TABLE 1

PATTERN OF INJURY: TEXAS CITY DISASTER, 1947

1. Multiplicity of lesions
2. Frequency of punctate lacerations
3. Frequency of fractures
4. Evidence of primary blast injuries
5. Absence of major burns and massive avulsion wounds in survivors

TABLE II
TEXAS CITY DISASTER CASUALTIES, 1947 SURVEY (2,400 PATIENTS)

Type of Injury	No. of Cases		Per cent
Minor injuries to soft tissue (including 44 burns)		1,496	62
Blast injuries		541	22
Eardrum perforations	274		
Unilateral	134		
Bilateral	140		
Internal blast effects	267		
Pulmonary	155		
Abdominal	74		
Kidney and bladder	26		
Acoustic trauma	12		
Orthopedic injuries		342	15
Amputations	31		
Major injuries to soft tissue (including 7 severe burns)		341	14
Injuries to head		217	9
Mild	161		
Severe	56		
Injuries to eye		123	5
Mild	85		
Severe	38		

by flying debris, injury from collapsing buildings, fire or drowning. Approximately 250 persons within the first zone reported no significant injury. In zone II (1,000 to 2,000 feet)—an area not heavily populated at the time—major injuries were found almost entirely in persons within buildings with an occasional casualty resulting from missiles. Many in the area, however, were uninjured or required only first aid procedures.

In zone III (2,000 to 3,000 feet) there were few deaths, and the majority of injuries were minor lacerations from broken glass and blast injuries, although a few persons had major lacerations from collapsing houses or from scattered missiles outside. This was a school and residential section.

In zone IV (3,000 to 4,000 feet), again a residential and school area, no deaths were reported. There were numerous minor lacerations, chiefly from glass, but few major wounds, and signs of blast injuries were uncommon.

TABLE III
DISTRIBUTION OF FRACTURES, 1947 (331 PATIENTS)

Type of Fracture	No. of Cases
Skull	35
Maxillofacial	17
Shoulder girdle and upper extremity	97
Sternum and ribs	48
Spine and pelvis	17
Lower extremity	97
Unclassified	31
Total	342

Injuries for the entire group of survivors and distribution of fractures are summarized in Tables II and III.

FOLLOW-UP SURVEY, 1956

Personnel covered by the two surveys are summarized in Table IV. Of the 184 patients who had not been listed in Red Cross or other official lists in 1947, a number had major injuries but were treated in private clinics or by their local physicians as outpatients. Data on those with serious fractures, major lacerations, etc., would probably have been collected initially had an attempt been made to obtain information from the members of the County Medical Societies involved in Texas City and adjacent areas.

A number of claims for very minor injuries

TABLE IV
COMPARISON OF 1947 SURVEY WITH 1956 SURVEY

	No. of Patients	Per cent
1947:		
Hospitalized	800*	33
Non-hospitalized	1,600*	67
Total	2,400	100
1956:		
Hospitalized	412	51
Non-hospitalized	392	49
Total	804	100
Previous records	620	...
New patients	184	...
Total†	804	...

* Round numbers.

† This included 749 adults (539 men, 210 women) and 34 children.

TABLE V
TEXAS CITY DISASTER CASUALTIES, 1956 SURVEY*

Type of Injury	No. of Patients	Per cent
Minor injuries to soft tissue (including 19 burns)	579	72
Eardrum perforations	269	33
Unilateral	126	
Bilateral	143	
Orthopedic injuries	251	31
Amputations	34	
Major injuries to soft tissue (including 1 severe burn)	187	23
Injuries to head	133	16
Mild	110	
Severe	23	
Psychoneuroses	72	8
Injuries to eye	67	8
Mild	26	
Severe	41	
Miscellaneous	82	10
Total	804	

* There were 588 patients with multiple-category injuries (73 per cent).

were undoubtedly fraudulent in nature. In the absence of physicians' records, demonstrable residual lesions or evidence which could be presented of time off from work, substantiation in doubtful cases was apparently made on the basis of individual F. B. I. investigations made in preparation for initial court action prior to April 1950.

The most striking difference noted in comparison of the various types of injuries in the 1947 and 1956 Texas City disaster surveys was the marked increase in patients with multiple injuries, with larger percentages in every category. (Table v.)

Blast injuries, other than rupture of the tympanic membrane, are conspicuously absent both in patients' complaints and in physicians' diagnoses. Present statistics correspond fairly accurately with those obtained initially in the hospitalized group of 800 patients rather than in the entire group of 2,400. Increase in each category may therefore be attributed in part to the fact that patients had very thorough physical examinations in 1956 and that initial records were incomplete, based primarily upon the most prominent injury and overlooking in particular eardrum perforations, mild fractures, and multiple lacerations, contusions, abrasions and sprains of minor consequence. It may be suspected, however, that in this large series of patients, who appear from their histories to be accident-prone both prior to and following the Texas City explosion, the long time interval and the absence of authenticated records have obscured the present diagnoses in some instances.

Minor Lacerations. One of the most notable findings in the study of the Texas City disaster victims originally was the large number of multiple punctate lacerations from small glass fragments. These have had a most favorable outcome from a cosmetic standpoint although many patients have asymptomatic embedded foreign bodies still evident on examination. In one patient a major pulmonary hemorrhage developed in 1951 from a glass fragment which had worked its way into the lung substance. The patient made a good recovery following segmental resection. It may be recalled that penicillin was used for the first time in 1947 on a mass scale in civilian patients, and undoubtedly the sensitivity of organisms which are now antibiotic-resistant must have contributed to the low incidence of infectious complications and to the fact that only a small group had rateable permanent disability (1 to 5 per cent) for disfiguring scars.

Orthopedic Injuries. A large number of residual orthopedic deformities exist, and delayed convalescence beyond three months has been attributed in the majority of cases to complications in healing of major fractures associated with injury to soft tissue but only rarely to osteomyelitis. There were a total of 443 separate fractures in 251 patients, with wide distribution. (Table VI.)

Primary Blast Injury. Since in the earlier survey of the Texas City disaster cases we were particularly concerned with primary blast injury, it has been most interesting to note in relation to previous perforation of one or both eardrums, the second most common type of injury, the significant incidence of varying degrees of permanent nerve-type deafness as determined by audiogram, although not as a rule within the range of useful hearing. In addition to the 269 patients who were diagnosed as

TABLE VI
DISTRIBUTION OF FRACTURES, 1956 (251 PATIENTS)

Type of Fracture	No. of Cases
Skull	31
Maxillofacial	20
Shoulder girdle and upper extremity	114
Sternum and ribs	115
Spine and pelvis	47
Lower extremity	88
Miscellaneous	28
Total	443

TABLE VII
COMPLICATIONS OF INTRACRANIAL INJURY

Complication	No. of Patients
Severe headaches	1
Partial loss of sensation in an extremity	1
Loss of smell	1
Impairment of hearing	3
Impairment of vision	3
Post-traumatic encephalopathy	2
Epilepsy (one with Jacksonian seizures)	3
Total	14

having perforation of the tympanic membrane, forty-nine others without substantiating records or scarring reported tinnitus and intermittent deafness.

In 1949, McReynolds, Guilford and Chase [4] reported treatment of seventy-seven blast injuries to the ear observed and treated at John Sealy Hospital by a uniform technique which included systemic penicillin, tetanus toxin-antitoxin, careful sterile cleansing, and light dusting of the canal and middle ear with sterile sulfadiazine powder daily for four to six days. With this regimen, true suppurative otitis media developed in only one of the patients, and only eleven perforations had not healed at the end of thirty days. In the patients with claims for otitis media either as an immediate complication or in episodes of chronic drainage, only three had not been treated initially elsewhere. Haphazard therapy and longer delay in reporting for treatment must have contributed to the increased incidence of difficulty and to the ratings of permanent disability for hearing impairment and infection. There were no instances of complaints suggesting permanent damage to the vestibular apparatus in spite of the proximity of patients to the blast center (within 100 yards in 80 per cent of the patients at Sealy Hospital).

Of the large number of patients (267) in 1947 who reported transient hemoptysis and hematemesis, chest pain, gastrointestinal symptoms, transient urinary retention and other presumptive evidence of primary blast injury at the time of the first survey (corresponding to lesions observed at autopsy of the fatally injured who were similarly exposed with reference to the explosion), scarcely a single one mentioned these phenomena in the history of his experience nine years later, having fixed more firmly in his mind injury to the eardrum and the more vague group of cerebral symptoms classified as mild "blast concussion."

Forty of the claimants had diagnoses of pulmonary injury, but for the most part these were associated with rib fractures, penetrating wounds or emboli as complications of multiple fractures. In one patient a diagnosis of probable blast injury was made by x-ray examination, with the findings of scattered areas of calcific stippling believed to represent calcified areas of hemorrhage. The original blast injuries to the lung appear to have been labeled as "acute chemical bronchitis."

Injuries to the Eye. In the forty-one cases of severe injury to the eye, the outcome was extremely poor, about half requiring enucleation and the other half having almost complete loss of vision in the affected eye. This was not true in the group of mild injuries, however, indicating that infection was not an important factor. A total of thirty-three patients without overt injuries to the eye complained of transient visual disturbances. Three persons had loss of vision from intracranial injury not associated with fractures of the skull.

Severe Injury to the Head. A total of twenty-three patients in the follow-up survey showed evidence of severe brain damage initially, in addition to three who died within the early period from multiple injuries. Residua were noted in fourteen (60 per cent). (Table VII.)

Major Injuries to Soft Tissue. Major injuries to soft tissue which occurred in 187 patients (23 per cent of the total) included one or more severe lacerations, contusions (including major back injuries), crush and avulsion

wounds, nerve and tendon trauma, and a small number of abdominal injuries. There was only one patient with severe burns who survived, and these resulted from acid rather than fire. Many of the lacerations were complicated by foreign bodies and infection. Eight patients with gas gangrene survived, and two died with overwhelming multiple injuries. Secondary closure of large contaminated wounds which were débrided initially and left open (at least at the University of Texas Medical Branch) was carried out as a matter of routine in addition to revision of amputations as indicated. There were, in addition, fifty-five secondary reconstructive procedures, primarily for nerve and tendon repair, for revision of disfiguring scars, and for replacement of tissue lost primarily by avulsion. Only a few permanent disability ratings were given above the 10 per cent level for major injuries to soft tissue *per se*.

Miscellaneous. A small group of complications were listed as major diagnoses on evaluation of residual injuries. These included, in addition to those mentioned previously, six instances of hepatitis (five from serum), one instance of renal calculi requiring repeated surgery, three hernias (two not verified as to etiology), and one case of hypertension on the basis of a Goldblatt kidney. Many patients in each category received compensation also for aggravation of existing conditions, especially arthritis and anxiety states. One patient had recently suffered from a coronary occlusion and was rated for aggravation of pre-existing heart disease. In another, an osteoma developed and one had marked vascular instability of the lower extremity following a fracture. In the miscellaneous category must also be mentioned thirty-four persons with fractured or loosened teeth either with or without associated fractures of the mandible and maxilla.

Psychoneuroses. At the time of the original survey, only two or three acute psychotic disturbances were noted among hospitalized patients; those on the Out-Clinic Service at the University of Texas Medical Branch who complained of "concussion," headaches, dizziness and the like had spontaneous subsidence of symptoms within a few months. The Neuropsychiatry Department reported remarkably few instances of compensation neuroses and believed that those patients with psychoneurotic complaints were already poorly adjusted prior to the disaster.

A total of 43 per cent of the patients reviewed in 1956 reported symptoms suggesting functional disturbances which were blamed on physical or psychological effects of the explosions: headaches, nervousness, weakness, inability to think clearly, difficulty in working, insomnia, bad dreams, back pain, indigestion, poor appetite, dizziness, palpitation, intolerance to cold weather, etc. The most bizarre complaint received was from a patient who had had a wound of the abdominal wall complicated by gas gangrene infection: "At night," he reported, "the gas rises up from my stomach into my nose and chokes off my breath!"

Although psychoneuroses were diagnosed in only 8 per cent of the patients and permanent partial disability ratings were given in a small number of cases, functional complaints contributed greatly to the periods of disability for which compensation was made. In the case of mild injuries to the ear, head and back particularly, subjective symptoms interfered considerably with accurate appraisal of residual impairment. Table VIII indicates that anxiety was by far the most predominant disturbance in the follow-up survey of disaster victims. Twelve of these patients received permanent disability ratings, and in one an evaluation of 100 per cent was given for severe hysteria and anxiety for a period of three and a half years until death ensued from other causes. Two patients committed suicide some time after receiving injuries of only moderate degree, but these were not considered to be related deaths.

Temporary Total Disability. In reviewing the present series of records it has been our impression that maximum periods of temporary total disability have been allotted to patients

TABLE VIII
PSYCHONEUROSES

Type of Psychoneurosis	No. of Patients
Anxiety (2 with hysteria, 2 with depression, 4 alcoholics)	61
Depression	6
Hysteria	3
Aggravation of schizophrenia	1
Stuttering (child)	1
Total	72

TABLE IX
TEMPORARY TOTAL DISABILITIES, 1956 SURVEY

Data	No. of Patients
Number of delayed deaths (12%)	21
Temporary total disabilities	783*
0–1 month (50%)	385
1–3 months (25%)	197
Over three months (50%)	201
Total	804

* Permanent disabilities 1 to 100%, 289 patients. (36%).

TABLE X
TEMPORARY TOTAL DISABILITIES, 783 PATIENTS

No. of Injuries Sustained	Length of Disability			Total No. of Patients
	Zero to Four Weeks	One to Three Months	Over Three Months	
Single category	183	26	7	216
Two	155	75	45	275
Three	38	60	64	162
Four	7	25	46	78
Five to nine	2	11	39	52
Total	385	197	201	783

for the following reasons: (1) effect of psychic trauma present originally or emotional difficulties developing between the time of the disaster and the presentation of claims in some instances; (2) absence of verifying data as to the time lost from work; and (3) prolonged unemployment following damage to industrial facilities or because of moving to other areas to look for new employment. It must be remembered, as well, that those concerned with "boarding" of each patient individually were in no way involved in the monetary settlement of claims and were not employed except as administrators of a duty involved in "compassionate responsibility," as established by Congress. In other words, everyone was given the "benefit of the doubt."

To summarize the records on temporary total disability three periods have been chosen arbitrarily. (Table IX.) In the first two the same ratings have been awarded for concurrent minor and major injuries regardless of the number of categories of trauma and the numbers of separate soft tissue lesions. For convenience in scrutiny of the various categories of disability, patients have been divided according to the number of injuries (Table V) and for the following periods: zero to four weeks, one to three months, and over three months. The last-named group extends in a few instances to two or three years. The majority, however, fall within a period of one year. It will be noted that the length of disability increases markedly in patients with the more severe injuries. (Table X.) The first period, zero to four weeks, includes one or more of the following: perforation of one eardrum; minor fractures (e.g., fibula, rib, finger, nose) and orthopedic injuries (mild sprains, bursitis); minor concussion; mild psychoneuroses, particular exaggeration of anxiety states in unstable persons; "acute chemical bronchitis" (interpreted in 1947 as mild blast injury to the lung); loss of one tooth; and minor injuries to the eye (chemical irritation, superficial foreign bodies); subconjunctival hemorrhage, minor lacerations. In addition, major injuries to soft tissue are included if they do not involve loss of tissue, do not involve more than one area of the body, and are not complicated by infection, deformity requiring secondary plastic surgery (e.g., depressed and adherent scars), or injuries to joints, tendons or nerves. Within the zero to four weeks period of time approximately half the patients were given one week or less temporary total disability. (Fig. 2.) In the majority there was no external evidence of injury, no medical records, no substantiating evidence of time lost from work, or else a single minor lesion. More time was allotted for lesions requiring suturing, prominent scars, perforation of the tympanic membrane, multiple lesions in a minor category, and substantiating records of injury or time off from work. In this large group permanent partial disability ratings of 1 to 10 per cent were given for aggravation of pre-existing emotional instability and arthritis, for cosmetic deformities and for minor residual orthopedic deformities.

The second group of temporary total disability patients includes those with minor injuries complicated by infection, retained foreign bodies, mild burns, and lesions requiring secondary plastic procedures. Major or single multiple-category injuries in this group are shown in Table XI.

When patients presented two categories of injury (a total of 285, or 35 per cent of patients in the 1956 follow up), a study was

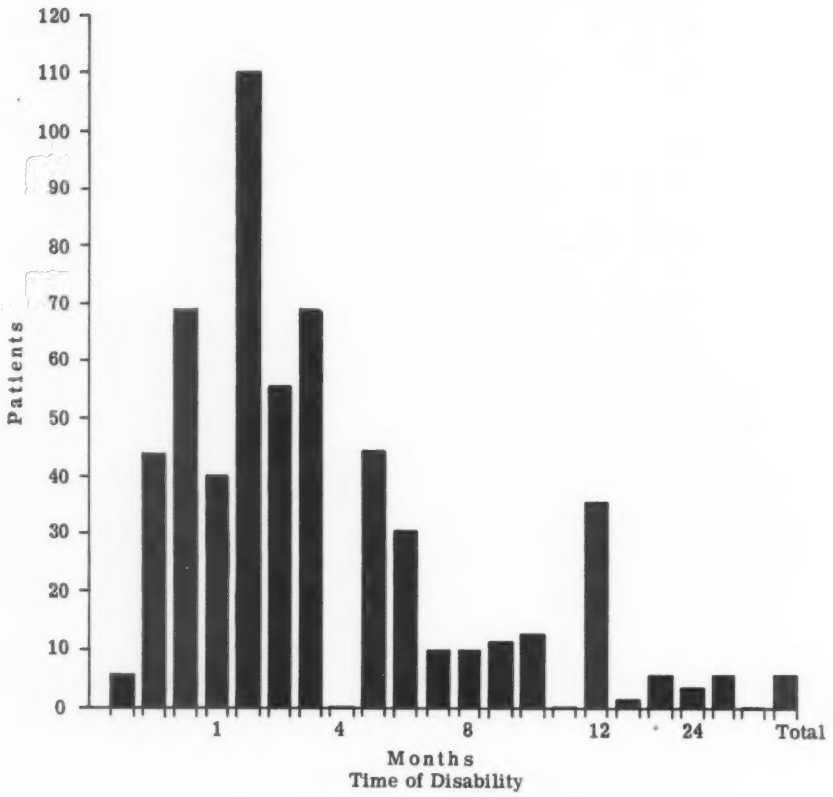

FIG. 2. Total temporary disabilities.

TABLE XI
TEMPORARY TOTAL DISABILITY (ONE TO THREE MONTHS)

1. Eardrum perforation
   Perforation of both drums, with or without drainage, or residual impairment
2. Orthopedic injuries
   Uncomplicated major fractures which characteristically heal within this period of time (e.g., humerus, simple skull, mandible, patella, clavicle, radius and ulna)
3. Major injuries to soft tissue
   Severe sprains and contusions of back, uncomplicated penetrating chest wounds, other injuries complicated by infection, loss of tissue, injury to nerve, tendon laceration (if multiple) and joint involvement
4. Injury to head
   Moderate intracranial damage
5. Injury to eye
   Severe injury to eye involving early enucleation, loss of vision from penetrating wound or intracranial damage
6. Functional lesions
   Severe acute episodes or aggravation of preexisting psychoneuroses in combination with minor injuries
7. Miscellaneous
   Loss of more than 1 tooth in combination with minor injuries, pulmonary injury associated with rib fractures

made of various combinations in order of frequency. These are shown in Table XII.

Partial permanent disability ratings in the group of patients receiving from one to three months' temporary total disability were given as in the previous group with 10 to 20 per cent for major hearing impairment or chronic ear drainage; more severe aggravation of arthritis or functional disturbances; bony defects of the

TABLE XII
COMBINATIONS OF TWO CATEGORIES OF INJURY

Category of Injury	No. of Patients	Per cent
Minor plus eardrum perforation	71	26
Minor plus orthopedic	48	16
Minor plus minor injury to head	41	14
Minor plus major	35	12
Minor plus functional	24	8
Minor plus eye	23	8
Miscellaneous combinations (14 possibilities)	43	14
Total	285	..

TABLE XIII
TEMPORARY TOTAL DISABILITY OF OVER THREE MONTHS: PATIENTS WITH THREE CATEGORIES OF INJURY

Category of Injury	No. of Patients
Orthopedic	37
Orthopedic plus ear	1
Orthopedic plus severe injury to tendon of arm	1
Soft tissue, including injury to tendon	9
Head	4
Functional	3
Ear (drainage)	2
Eye (one or both)	3
Eye plus ear	1
Eye plus nerve	1
Pulmonary	1
Aggravation of existing arthritis plus minor injuries	1
Total	64

TABLE XIV
TEMPORARY TOTAL DISABILITY OF OVER THREE MONTHS: PATIENTS WITH FOUR CATEGORIES OF INJURY

Category of Injury	No. of Patients
Orthopedic	26
Orthopedic and soft tissue	2
Orthopedic and functional	1
Functional	4
Soft tissue	6
Head	1
Ear	1
Eye	1
Eye and soft tissue	1
Cardiac	1
Lung	2
Total	46

TABLE XV
TEMPORARY TOTAL DISABILITY OF OVER THREE MONTHS: PATIENTS WITH MORE THAN FOUR CATEGORIES OF INJURY

Category of Injury	No. of Patients
Orthopedic (amputations, multiple fractures, complications alone or in combination with injuries to soft tissue)	25
Injuries to lung and embolism	5
Functional	4
Soft tissue, severe or with plastic surgery	2
Head (1 in combination with amputation)	2
Prolonged ear infection	1
Total	39

skull; and impairment following fractures and major injuries to soft tissue. Included in the 20 to 30 per cent category were patients with loss of one eye or loss of vision in one eye, amputation of the lower extremity and more severe impairment following fractures.

The 201 patients receiving total temporary disability of more than three months were for the most part in the multiple injury categories and increased in percentage according to the number of separate severe traumatic lesions. (Table x.)

No patients with minor injuries were included in this group. Single-category major lesions included a severe acid burn requiring skin grafting; crushing injury to one foot; fractures of the thoracic and cervical vertebrae; one injury to soft tissue complicated by severe infection and one by avulsion of muscle; and a severe injury to the hand. Patients with two concurrent major injuries included for the most part severe intracranial injury with residual functional or organic complaints; several acute psychoneuroses in addition to injuries requiring hospitalization; and open reductions of fractures with injuries to soft tissue.

Patients with three or more concurrent categories of injury have been analyzed in detail with respect to the major causes of disability extending over a three-month period. As may be seen from Tables XIII, XIV and XV, the major cause has been orthopedic in more than half the cases.

Patients with multiple categories of injury (over two) account for the higher percentages of permanent disability ratings. Of the five in the 100 per cent category (1 per cent of the total), four died within four years. The 60 to 90 per cent groups comprised only 2 per cent of the total permanent disability ratings. These included amputation plus a major disability, e.g., severe injury to the head or loss of an eye, a crushing injury to the back with complications, and similar combined lesions. Patients with 40 to 50 per cent and 50 to 60 per cent (each 3 per cent of the total) had injury to both eyes, amputations of the arm, amputation of the leg plus severe disability in another cate-

TABLE XVI
RELATED DEATHS, 1956 SURVEY

Time of Death	No. of Patients
Within 24 hr.:	
Partial evisceration, shock	1
Injury to head	2
Multiple lacerations, shock	3
Within 48 hr. to 2 wk.:	
Injury to head (1 with severe injury to lung, 1 with multiple fractures and gas gangrene)	3
Internal injuries (1 with gas gangrene)	2
Transection of spinal cord, internal injuries	2
Within 2 to 4 wk.:	
Pulmonary embolism	2
Injury to head, gangrene of extremity, acute renal failure	1
Within 1 to 2 mo.:	
Pulmonary embolism (1 with gas gangrene also)	3
At 14 mo.:	
Transection of spinal cord	1
Total	20

TABLE XVII
PREVALENCE OF HYPERTENSION (180/105 MM. HG) ACCORDING TO MULTIPLICITY OF INJURY

Multiplicity of Injury	Per cent	Total No. of Patients
One category	7.3	177
Two categories	11.0	218
Three categories	12.0	124
Four categories	13.9	65
Over four categories	19.5	46

gory, and permanent brain damage for the most part.

In reviewing the permanent disability ratings, it is apparent that each patient's residual defects received the most careful scrutiny on the part of the team of Army examiners and that every attempt was made to follow the standards set forth by McBride [5] in the Veterans Administration Disability Manual and by other authorities to allow for compensation to patients on the basis of age and individual economic disability. When applicable, evaluation was also made for future medical expense to allow for replacement of protheses and for remedial surgery.

Estimates for physical pain and suffering throughout the evaluations were rated minor, moderate and severe for periods of time corresponding roughly to the period of temporary total disability or for somewhat shorter periods in the case of minor injuries. Minor injuries were categorized as producing minor pain and suffering; most major injuries, moderate pain and suffering. Injuries to the eye, intracranial lesions, amputations and severe cosmetic deformities accompanied by depression were rated as producing severe pain and suffering, at least for short periods of time. In the absence of access to medicolegal records, it is difficult to assess the influence of these ratings on the amount of final settlement. It is evident, however, that functional diagnosis of mental pain and suffering must have added to the monetary compensation in every instance or at least influenced the claim board in its evaluation of the total "compassionate responsibility" to be assumed by Congress under the Texas City Claims Act.

A total of twenty patients in the series reviewed died as a direct result of injuries sustained in the Texas City disaster. A summary according to the time of death and contributing causes is given in Table XVI.

Hypertension. Upon the arrival of the first Texas City casualties to the University of Texas Medical Branch Hospitals in 1947, it was observed that a number of patients had elevation of blood pressure, especially of the diastolic component. These were studied by Ruskin and Beard [6], who found diastolic maximal readings of 95 to 160 mm. Hg in a total of 103 of 180 persons. Follow-up records in 111 showed subsidence of blast hypertension except in twenty-four of the group. This incidence was believed to be significantly higher, however, than for the general population according to information from industrial and insurance records, even taking into account hereditary and other predisposing factors. It was noted that during the four- to eight-month period of the follow-up investigation in outclinic patients the majority of blast victims "complained of nervousness, various aches and pains, and particularly hypersensitivity to loud noises." These were the first clues to the symptoms which are reported in such dramatic numbers in the patients filing claims in 1956 under the Texas City Disaster Act. Their early appear-

TABLE XVIII

INCIDENCE OF HYPERTENSION BY AGE AND SEX IN TEXAS CITY DISASTER FOLLOW-UP GROUP*

Blood Pressure Readings (mm. Hg)	Age (yr.)									
	16–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–60	60–
Males										
140/90	28.0	20.0	36.8	28.5	45.1	43.1	57.8	51.1	65.5	69.0
	(13.1)†	(18.3)	(20.4)	(24.6)	(29.1)	(32.8)	(37.9)	(46.2)	(54.4)	(60.3
150/90	.....	15.0	21.0	24.5	23.5	31.0	35.1	40.4	44.4	57.1)
	....	(12.5)	(14.5)	(17.9)	(23.3)	(25.4)	(29.6)	(37.8)	(41.8)	(48.5
150/95	....	....	15.8	6.1	13.7	27.6	29.6	31.9	36.1	50.0)
	....	....	(5.9)	(8.4)	(12.1)	(12.9)	(18.4)	(24.5)	(29.1)	(38.0
150/100	....	....	10.5	4.1	13.7	25.9	25.9	25.5	27.7	47.6)
	....	....	(5.1)	(6.6)	(9.5)	(10.2)	(15.8)	(22.2)	(27.7)	(36.9
180/105	....	....	5.3	....	7.8	13.8	14.8	21.3	16.6	28.5)
	....	....	(0.6)	....	(1.5)	(1.1)	(3.6)	(4.3)	(6.4)	(8.2)
Females										
140/90	10.0	12.5	....	12.5	43.5	35.7	57.1	50.0	87.5	85.7
	(5.3)	(6.9)	....	(13.1)	(20.8)	(26.5)	(39.4)	(50.6)	(52.2)	(64.4)
150/90	....	....	....	4.2	34.8	21.4	47.6	50.0	75.0	71.3
	....	....	....	(10.6)	(16.4)	(20.2)	(30.1)	(41.8)	(42.1)	(51.8)
150/95	....	....	....	4.2	26.1	14.3	38.1	33.3	37.5	64.2
	....	....	....	(5.1)	(7.1)	(12.5)	(20.8)	(30.2)	(33.4)	(43.5)
150/100	....	....	....	4.2	21.7	14.3	28.6	16.6	37.5	64.2
	....	....	....	(3.6)	(6.1)	(11.1)	(19.0)	(28.8)	(31.0)	(40.8)
180/105	....	....	....	....	17.8	14.3	28.6	16.6	31.2	50.0
	....	....	....	....	(1.1)	(2.7)	(5.1)	(8.4)	(6.6)	(13.1)

* Cases are included if either systolic or diastolic reading is within specified limits.

† Figures in parentheses are percentages for normal prevalence of hypertension (Master et al. [7]).

ance in the lower income group of patients is perhaps significant, at least with respect to nervousness and multiple somatic complaints.

We were most interested in the 1956 claim studies to consider the problem of hypertension. Using the standard tables of blood pressure range with respect to age, sex and other influences which were published in 1950 by Master, Dublin and Marks [7], it would appear that the Texas City disaster follow-up group have a greater percentage of hypertension than the general population, particularly at high levels. Of the 622 patients with single blood pressure recordings, 265 (42.6 per cent) were found to have a reading of 140/90 mm. Hg or above, considering all age brackets and discounting hypertensive medication. This incidence corresponds to that normally prevalent in the fifty to fifty-four year old age group in both men and women. A total of 39.1 per cent of patients had blood pressure readings of 180/105 mm. Hg or above. Although the blast *per se* cannot be implicated directly by review of the patients' distance from the explosion site and noting whether or not they were indoors or outside at the time, the number and severity of lesions in the individual patient have an apparent effect on the development of hypertension in the upper range levels. (Table XVII.) Analysis of blood pressure readings of 140/90 mm. Hg and above by age and sex have been made for comparison with percentages quoted by Master et al. [7] for large groups of the general population. (Table XVIII.) In Ruskin and Beard's follow-up group of 1947 patients, single blood pressure readings are available in seventeen of the twenty-four (one died, three did not present claims, and three had no recordings made). Ten of the seventeen (58 per cent) are still hypertensive.

SUMMARY AND CONCLUSIONS

The medicolegal aspects of trauma are inescapable and often present problems of great magnitude. In the present instance litigation lasting for such a long period of time and the lapse of years prior to evaluation of Texas City disaster injuries must surely have confused the picture of the original lesions in many instances and added greatly to the burden of the personnel involved in processing the claims. Certainly every effort was made to be both fair and generous, and maximum partial total disability ratings were awarded to allow for loss of over 48,000 days from work and ordinary activity in the 539 men, 210 women and thirty-four children who comprised the group of claimants. Partial permanent disability ratings were assigned to correspond to the accepted standards of rating.

It is indeed surprising that so many persons who had been involved in the 1947 explosions did not file claims prior to 1950 when the original suits were prepared, and that a large group who had filed claims previously did not apply for reimbursement under the Texas City Act even though they were known to be living in the area for the most part and some had suffered major injuries. Of those who were reimbursed in amounts up to a maximum of $25,000.00 (less 10 per cent legal fees), a total of 184 had not been covered in the original survey of 1947, largely because they had trivial lesions or were treated in small private clinics as outpatients for minor surgery and after-care. There were discrepancies in accounts of injuries initially and omission of some multiple injuries but, on the whole, the original records were of great value in reviewing each case and lent support to claims in doubtful cases. The physical examinations conducted by and under the supervision of the Branch Office of the Surgeon General were most thorough although little follow-up information on blast injuries, with the exception of eardrum perforations, was obtained from the records or from patients' complaints. This is understandable in view of the fact that no provision was made for research investigation in connection with the processing of claims.

In summary, the medical follow-up examinations of the Texas City disaster patients demonstrated the same general pattern as in the original survey conducted in 1947 except for an increase in multiple injuries of all kinds, the prominence of functional complaints which contributed greatly to the periods of disability and suggested both real and assumed psychic trauma residua, and the absence of presumptive evidence of internal blast injury. It was noted that minor injuries to soft tissue had healed well with a minimum of cosmetic disfigurement. The majority of eardrum perforations were associated with subjective hearing impairment, and even without gross evidence of deafness there were varying degrees of permanent nerve-type deafness, as determined by audiogram. In reviewing the fractures a large number of deformities were found, often in association with major injury to soft tissue and accounting for delay in recovery of the majority of patients who were disabled beyond an arbitrary three-month period. Patients with severe penetrating injuries to the eye did poorly, as might be expected; those with mild injuries to the eye, on the other hand, showed good recovery.

To those of us who participated in the handling of the Texas City disaster victims in 1947 *triage* was a new word, and mass casualty planning was in its infancy before the analysis and release of data with respect to the thermonuclear detonations at Hiroshima and Nagasaki. In spite of the fact that the explosions of ammonium nitrate compound in our community area in no way compared with a single small-yield atomic bomb nor with the repeated experiences of European cities during World War II, it was an exceptionally well documented civilian disaster with both blast and miscellaneous multiple injuries. There was, characteristically, an initial deluge of patients in the early hours following the explosions (about 600 to 800 at the John Sealy Hospital). Following first aid, minor surgery and evacuation to convalescent units approximately one-fourth remained in the hospital at the end of the first day. Except for the most severely injured, there was a very rapid decrease in census, particularly during the first four weeks.

Even though persons with severe burns did not survive to be rescued and treated and there were no radiation hazards, the resultant casualties can be compared with those which might be expected in a metropolitan target area today after advanced warning of nuclear attack and evacuation of the urban population. Study and experience in the handling of mass casualties are of the utmost importance in the

establishment of an orderly chain of command, which in time of crisis is the basis of catastrophic medicine and may be the key to the elimination of chaos.

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DISCUSSION OF PAPERS BY DRS. LINDSEY; HOWARD, EBERT, BLOOM AND SLOAN; CASBERG, BLOCKER, LEVIN AND DUNTON; AND BLOCKER, BLOCKER, GRAHAM AND JACOBSON

Kenneth F. Lowry (Troy, Ohio): I wish to congratulate Col. Lindsey on his interest in and investigation of anaerobic gas infection, more specifically, clostridial myositis.

It is most gratifying to learn that this infection, an ever present possible complication of all massive wounds, particularly war wounds, is still being investigated and studied even though we are not at present engaged in a major war.

Our problem now is to attempt to correlate this mass of experimental data with the clinical findings and experience most of us have had with war wounds and some civilian wounds.

During World War II we saw many patients with right thoracoabdominal injuries in whom clostridial infection developed in the right pleural cavity and clostridial myositis at the wound of exit. In one such case a clinical diagnosis was not made until approximately forty-eight hours postoperatively. The myositis spread to the muscles of the right flank, back and both buttocks, and anuria finally developed. Despite heroic efforts made to control the myositic infection, the patient died following a pre-terminal coma on the fifth postoperative day.

I was amazed at the number of Col. Lindsey's observations which corresponded to our clinical findings. During the war we had to evaluate or diagnose clostridial myositis on a clinical basis alone. Bacteriological examination was not at all infallible because clostridia were found in a very high percentage of all our wounds. However, regarding etiology, we did establish certain criteria which were of help to us. I will go through these very briefly.

First, clostridial myositis was more prone to develop in wounds complicated by compound fractures. Second, clostridial infection was more prone to develop in wounds complicated by vascular injury. Third, clostridial myositis was more prone to develop in wounds of the thigh, leg and buttocks than in other parts of the body. Fourth, the incidence of clostridial myositis was in direct proportion to the fecal contamination of the soil where the injury was obtained.

I would like to comment briefly on the last observation. The contrast between the dirt, filth and mud of the terrain south of Casino (a countryside whose well fertilized fields and hillsides have been under cultivation for thousands of years) and the sands of the Western desert or the windswept plains and stony hillsides of Tunisia gives us presumptive evidence, at least, for the marked increase in the incidence of gas gangrene in Italy as compared to North Africa.

Fifth, the incidence of clostridial myositis was directly proportional to the type or magnitude of the wound obtained. Sixth, the incidence of clostridial myositis was higher when woolen clothing was being worn at the time of injury.

This brings us to a very interesting correlation with Col. Lindsey's observations, in that a clostridial infection uniformly developed in his goats. One wonders why this occurs when the organism was not introduced, but we found that the incidence of clostridial myositis was much higher when woolen clothing was being worn at the time of injury.

After examination of samples of wool, cotton and silk clothing, some of which were dry cleaned and steam pressed, a number of investigators found clostridia in almost all the wool samples whether they were cleaned or not, while none were found in cotton or silk. Of course, a sheep is very closely related to a goat.

Next, the incidence of clostridial myositis was directly proportional to the time interval between the injury and the application of the initial dressing; it was also proportional to the time interval between the injury and the initial operation. In that respect, I wonder if some of Col. Lindsey's animals might not have survived had he performed a very high amputation.

The diagnosis of clostridial myositis was, in our experience, definitely clinical and not bacterio-

logical. With that in mind, the following diagnostic criteria, although quite elastic and certainly not infallible, were found useful in helping to establish a diagnosis.

1. Toxemia; this was a constant finding. In early cases this might be manifested only by an overalertness and an overanxiety for personal welfare. Col. Lindsey observed that his goats were very alert.

2. A high pulse rate, usually over 120, and out of proportion to the degree of infection or temperature. As the infection increased, the pulse rate became more rapid and of a poor quality.

3. Pain, often very severe at the site of injury. Occasionally patients complained of a sense of weight, heaviness or lightness in the wounded extremity before the onset of pain. Col. Lindsey was not able to observe pain in goats.

4. Elevation in temperature, rarely over 100° to 102°F. This was also a finding of Col. Lindsey's. The goats had very little rise in temperature, and it was not proportional to the degree of toxicity.

5. Low blood pressure.

6. Anemia was almost always present and varied with the length of the infection and the degree of toxemia.

7. The wound. Discharge varied from a slight watery or a dirty brown one to a very profuse, serosanguineous one. The odor was inconstant, varying with the secondary wound invaders. If present, it was usually putrid or like decayed meat in character. The odor of the wound was definitely of no value as a guide in diagnosis. Crepitation certainly was not a reliable sign, and it was often absent until late in the infection; this corresponds to Col. Lindsey's finding.

I am sure Col. Lindsey is familiar with the work of Butler. I would like to ask him to comment on that. The technique which Butler proposed seemed to offer hope that the problem of diagnosis might be much simplified. The degree of capsulation of the organisms, together with the extent of damage to leukocytes, as revealed in specially stained direct smears, provided her with a reliable index of the severity of the infection. Thus, heavy capsulation, with damage to leukocytes, pointed to an active invasive infection (clostridial myositis). Conversely, poor capsulation, active phagocytosis and lack of leukocyte damage, all indicated that a severe invasive infection was unlikely.

In conclusion, I would like to state that although World War II and the more recent Korean conflict, plus this excellent experimental work of Col. Lindsey, have provided an opportunity for an improved knowledge of these infections, the problem has not as yet been satisfactorily solved.

It is our earnest hope that laboratory and clinical investigations will be relentlessly continued, so that in the event of another war we may better cope with this deadly complication of traumatic wounds. Our dream, of course, lies in the direction of active immunization with a combined clostridial toxoid which will render the same remarkable protection which tetanus toxoid provided during the recent war.

MORRIS J. FOGELMAN (Dallas, Tex.): Up to 1940 therapy for fluid replacement in cases of trauma was characterized by the administration of salt solutions. During that period it was universal that practically all injured patients in need of some type of fluid replacement other than blood received salt solutions.

The period from 1940 to 1950 was characterized by the "no salt" thesis. "Do not give salt solutions to patients. They cannot excrete it. They cannot handle it under conditions of major injury and under operation." As a result of this philosophy, many patients who were in need of salt solution as replacement therapy did not receive it. From 1950 to the present time there was a revival of the administration of salt solution. Its use has been demonstrated to be efficacious as a substitute for blood as a plasma expander and certainly when there is a need for its replacement, when it is lost externally or by distributional shifts in many forms of injury.

When the use of dextran was first developed, there were many who stated on clinical experience that it was a very effective plasma expander. Its use was heralded throughout this country and in many parts of the world as the most superior repair solution to administer until blood was available. This thesis was accepted so widely on a clinical basis alone that I think it drove many of my friends, some of them in parts of Texas, to accept it as very efficacious and to concur in stockpiling dextran solutions for national defense measures.

In the last few years it has become evident that dextran solutions without salt in them are of no value in treatment as plasma expanders. In other words, all the dextran marketed today is made up in a saline solution. The most important question relative to the use of dextran is this: is dextran more efficacious in the treatment of hemorrhagic shock than salt solution alone until blood is available? I do not think it is, and I certainly do not believe that the problem has been settled.

There is a small group of iconoclasts in the northern part of Texas who believe that lactate-Ringer's solution is as effective as dextran in saline for immediate volume expansion. A bottle of lactate-Ringer's solution costs a few cents compared to $6.50 for 500 ml. of dextran. Unless one can say beyond a doubt that dextran is a more effective repair solution than saline alone, then perhaps it is true that there is a dilemma both here and in Washington relative to the continued use of dextran. I am gratified that dextran has not been

adopted more widely. Our animal experiments well fortify our belief that it is not any more effective than saline alone; it is too expensive and is not worth the cost.

I well realize there are a good many contrary opinions, but I believe they are based on clinical experience and by and large are not well founded.

When one considers the small amount of dextran that has been used throughout this country, there is fear, as Dr. Howard has alluded to, that unless it is used more widely it cannot be produced on an economical basis. It is time we stop and question its use. If we believe that salt solutions are efficacious and as effective as dextran in the treatment of hemorrhagic shock until blood is available, and we all believe there are no blood substitutes, I think we will find ourselves back in a salt era saying again, perhaps as in the old days, that a saline solution should be administered until blood is available, and that salt solutions, if anything, should be stockpiled.

JOHN P. NORTH (Dallas, Tex.): I wish to discuss one of the several very interesting aspects of Col. Lindsey's presentation, namely, the influence of the vascularity of the limb upon the development of clostridial infections. I do not know how to explain his finding of prolonged survivals following ligation of the major vessels. I have always felt very strongly that damage to the blood supply of the extremity is the most important determining factor in the way these infections behave once they have taken hold.

We had considerable experience with gas gangrene and with localized clostridial infections during World War II, as I reported at the meeting of this Association in San Antonio twelve years ago. We found that our cases separated themselves unvaryingly into two groups.

In the first group there was damage to the blood supply in the form of damage to the major artery above the knee or above the elbow, or damage to both vessels below the knee or elbow. In this group true gas gangrene developed. Not a single patient survived without amputation, and the mortality rate was high.

In the other group with blood supply reaching the part, there was localized infection which could be handled by débridement with excision of muscles or groups of muscles. Not one patient in that group required amputation. All survived with the exception of one patient with involvement of the abdominal wall which could not be adequately débrided. It would seem to me that blood supply is of the utmost importance.

I am not convinced that Col. Lindsey is producing in his goats the picture of gas gangrene or clostridial myositis as we see it clinically. I think his animals may well have localized clostridial infection but this has an entirely different significance than the gas gangrene with which we are all familiar clinically.

J. W. BLUNT, JR. (Cleveland, Ohio): We have been doing some work in our laboratory that has bearing on the papers by Col. Lindsey and Dr. Howard and co-workers. There is a protein complex in the animal blood stream called properdin which is the first line of defense against bacteria. By adding high molecular weight dextran to the animal's blood, the properdin is neutralized and the animal dies of overwhelming infection. For example, if a rat is given 1,000 Bacillus coli organisms it barely affects him, but if he has had a shot of high molecular weight dextran and then is given 2,000 B. coli organisms, he will die of overwhelming B. coli septicemia in twenty-four hours. The problem has been that some of the clinical dextran from 1952, 1953 and 1954 that we have tested does contain some large molecular weight fractions with considerable lowering of the properdin level. The more recent material has not given us trouble. I wonder, Dr. Howard, if there is any effort being made to remove some of this older dextran from the stockpile.

Since tissue damage releases large amounts of properdin-binding polysaccharides, I wonder if this may contribute to the mortality in Col. Lindsey's goats. Are you determining properdin levels in your animals?

JOSEPH R. SHAEFFER (Washington, D. C.): I am deeply appreciative of the several papers presented in this section of the program, for each of them deals with some aspect of the disaster problem. I would like to comment on each one.

I have been very familiar with the work of Col. Lindsey and because of its significance I sincerely hope that circumstances permit him to continue in this effort. Although his results have a frustrating quality he concludes with some confidence for a breakthrough in this problem and offers a glimmer of hope for the future. Certainly in a mass casualty situation gas gangrene could be a tremendous influence on survival for many with mechanical injuries.

The papers of Drs. Howard et al. and Casberg and co-workers are related. I prefer to interpret their discussions as a plea for more vigorous action in these two areas which have to do with the national defense effort.

I believe Dr. Fogelman's contention that saline solution is an equally satisfactory resuscitative agent is contrary to scientific evidence, but there are others better qualified than I to discuss this problem.

I believe that the paper by Dr. Howard and co-workers presents a real challenge to the medical profession in terms of national defense. It has been surprising to me that during major disasters many physicians were unfamiliar with dextran and there-

fore were afraid to use it. To me the problem is one of familiarization and understanding of its value as an expediency during the initial and frequently critical phase of casualty management. Certainly its value was well demonstrated during the Korean conflict. In a mass casualty situation it would be an invaluable adjunct.

All are aware of the fate of PVP which was extensively used during World War II without deleterious effects. I do not believe our judgment is sound if we permit dextran, for one reason or another, to meet a similar fate.

Dr. Casberg and his associates defined one method for overcoming the undesirable viral hepatitis factor of pooled plasma, namely, that of pasteurization. For several years now we have known that sterilization at room temperature is an effective although time-consuming process. Admittedly, plasma is a better expander than dextran. Again, in terms of the national defense effort, I am concerned that we have not paid more attention to re-stockpiling sterilized plasma because of its known superiority to dextran, albumin or other blood substitutes.

I am reminded of the current status of the plastic bag for collection and transportation of these agents in times of national emergency. I believe it has been accepted that plastic bags will replace glass bottles. I am also aware, however, that familiarization with the bag is essential in time of peace if the transition is to be prompt and effective in time of war. Such experience should be an important part of our training.

The paper by Dr. Blocker et al. is a most unusual follow-up study and statistical analysis, unlike any I have ever read and perhaps will ever see again. Remember that the adjudication of the claims in the Texas City disaster was a result of an act of Congress. With the introduction of compensation into the picture all possible claimants quite naturally appeared.

Dr. Blocker and others assigned to the task, however, were protected by previous investigations of legitimacy by the Federal Bureau of Investigation. Obviously, careful evaluation and documentation was essential to the mission. I am sure most of you are familiar with the initial report.

In this report I recognize the painstaking analytical study of Dr. Virginia Blocker. Many might find this report rather dull reading, but I would like to point out that it is an unusually well controlled follow-up study in that practically all cases reported in the original study were subject to re-examination.

In closing I would like to make mention of the NATO Handbook on Emergency War Surgery. This handbook was conceived at the NATO medical meeting in 1952 when Dr. Casberg was Deputy Secretary of Defense, Health and Medical. At that time it was felt that the efforts toward standardization of the activities of the NATO nations should be extended to include the basic principles of emergency care for casualties. The United States supported this concept, no doubt to assure proper and adequate care for our personnel following injury. In any event we were aware that TB Med 147 (written as a guide during World War II) was outdated in Korea and in need of revision.

A committee was formed to produce the Handbook, with Gen. Sam Seeley as the Chairman. I am not familiar with the number of surgeons who participated in this effort but believe they were experts in their particular field. It was Gen. Seeley who "rode herd" on these writers to complete their assignments, which resulted in the first edition. This was presented at the NATO meeting in 1957 for adoption, translation and reproduction by all NATO member nations.

I attended that meeting and pointed out that there was much redundancy, reduplication and inconsistency which could be eliminated. It was further lacking in reference to the problems of the nuclear age.

Our own Department of Defense subsequently established an *ad hoc* committee under Gen. Seeley for consideration of its adoption. I was given the task of revising the text and did so, leaning heavily on the invaluable advice and service of Miss McFetridge of the Historical Unit of the United States Army Medical Service.

The Handbook is concerned only with the treatment of casualties in the forward area and deals with emergency treatment through the first surgical echelon; it does not consider definitive treatment. Although it was written for the military, the principles are equally applicable to civilian experience.

I am happy to report that it has been accepted by the Trauma Committee of the American College of Surgeons as being complementary to their two manuals on "Fractures" and "Soft Tissue Injuries." I have good reason to believe that it will be adopted by Federal Civil Defense Agencies for their assemblies. It is being accepted by most MEND programs as a training text. I believe you will find the language direct, succinct and accurate.

Its size is such that it will fit in the pocket. This was intentional for it was not meant to be a volume for the bookshelf but rather one made readily available as a reference. Each member of the Armed Forces Medical Corps has been given one, which policy will be followed for all new medical officers. I believe you will find it very valuable for the purpose for which it was written.

Curtis P. Artz (Jackson, Miss.): Two areas associated with trauma have been brought out in this last group of papers that require summarization and emphasis. The first one is the problem of

infection. As we have known for many years, one of the major unsolved problems in the injured man is infection.

Col. Lindsey emphasized that the volume of tissue destroyed in the goat had a great deal to do with prognosis. We have seen this for several years in burns—the larger the amount of tissue destroyed, the poorer the prognosis. Dr. Williams also brought out in his studies on abdominal injuries that the number of organs damaged and the associated injuries increased the mortality rate. A high percentage of persons die from infection, probably from the inability to counteract infection.

I would like to ask Col. Lindsey if he feels that the mechanism of death in goats is a toxemia.

The second important aspect of trauma brought out is that of supportive therapy. Being a Texan, I have great respect for my confreres in the state but Dr. Fogelman and I really could not agree on the fact that dextran in saline is no better than saline alone. I think that his group in Dallas has some experimental information that would lead one to suspect this finding. However, there are other laboratories, such as the Army Surgical Research Unit, that have found dextran in saline far superior to saline alone in animal experiments. There is now abundant clinical evidence supporting the fact that dextran is of value. We should continue to stockpile it unless we find something much better. One of the reasons that dextran has not been used more is not the fact Dr. Fogelman emphasizes but that undue importance has been given to its potential to cause bleeding. My friends tell me, "I am afraid to use that dextran because I read someplace or I heard Dr. so-and-so say on some famous panel that it might cause bleeding." In a broad experience in Korea, dextran did not cause any bleeding.

I have enjoyed this discussion very much and I urge further studies on the new preparation Dr. Casberg and his co-workers have presented. I also hope you return home with a determination to delve further into the problems of infection in the injured patient.

Douglas Lindsey (closing): I am deeply grateful to you gentlemen for asking these questions, and I will try to answer them quickly and *in toto*. I have a good excuse, Dr. Blunt, for having no data on properdin. As I said with pride and plaintiveness, all work was done by me singlehandedly. I did 10,000 quantitative bacterial determinations but I am sorry I cannot do a properdin determination.

I agree with Dr. North that we may have a different disease here. I am familiar with his work. I deliberately did not quote his paper or other clinical papers because I do not feel I can speak clinically on what this is or what it means. This *is* a severe infection. It *is* a myositis. It does not spread, however, beyond the hind quarters. I have never seen a spread of this infection beyond the muscle attachments to the pelvis. There is very severe vascular damage in these cases and a very massive wound.

Amputation, Dr. Lowry, is quite effective if it is performed early. If it is done within six hours the animal lives indefinitely. It can be delayed to twelve hours by certain conservative means with ice and so on, but it cannot be delayed more than twenty-four hours unless local penicillin or local neomycin-bacitracin is used. I know that the promotion of local antibiotic treatment is heresy to a surgical group but we cannot delay amputation using intramuscular or intravenous antibiotics; we can with the local.

We have tried to look at the organisms to find out whether they are particularly virulent. By Butler's standards, I think not. We never see white cells in the wound exudates of the animals beyond about four hours. However, the organisms are not particularly heavily encapsulated, and I do not think they are unusually virulent. I will give you one example.

I have twice cut my hand into the muscle doing an autopsy on these goats. On one of these two occasions I deliberately took no antibiotics and the wound healed without delay.

I think the reason we get the infection in these animals is due to the factor of high velocity. There is considerable vascular damage to the muscle.

Regarding Dr. Artz's pertinent question about toxemia, the animals, I think, do die of toxemia. They die a characteristic death; they cry out, they show hypermotility. They die with their eyes open with a stark expression of fear, as much as I can interpret the psychology of the goat. They show other evidences of toxemia, for example, depression of the respiratory rate of the cardiac muscle in the Warburg apparatus. However, I would like to raise the question of what *is* this toxemia. It is not circulating alpha toxin in the blood. That toxin is not there.

As far as I can tell, this is some sort of a toxin which is a breakdown of muscle products. In that respect there may be some tie between clostridial infection, fat embolism, the crush syndrome and so on, but it is not circulating alpha toxin, and I think this is one of the reasons why the transfusion of 500 ml. of antitoxin intravenously does not help these animals at all.

To answer Dr. Artz's question further, as to what role toxemia plays, the clostridial infection is not the only factor in this preparation. If we completely control the infection, the animal will still die in sixty hours. He dies of whatever it is we call shock. On the other hand, if we completely control the shock with blood transfusions, the infection kills the animal in forty-eight hours.

These things tie together, and this can be shown by multiple regression analysis.

We took a certain animal with severe reduction in blood volume and a high clostridial count. With the regression formula we predicted it would live eleven hours with a stated 95 per cent confidence limit of nine to fifteen hours; it lived eleven hours.

We took another animal on the other end of the scale—very low reduction in blood and a very low clostridial count. We predicted it would die in sixty hours and it did.

We took an animal treated with penicillin but with a very high clostridial count in spite of that treatment. We predicted it would live fourteen hours, with confidence limits of eleven to seventeen hours. It lived twelve hours.

These are 95 per cent confidence limits, so one case in twenty will be misjudged.

We took an animal not treated with antibiotics but still with a very low clostridial count. We predicted the animal would live forty-four hours, which is more than 4 standard deviations beyond the expected mean survival time. It only lived thirty hours, which is outside the confidence limits but 3 standard deviations beyond the mean, so we think that we have a fairly good quantitative relationship between shock and toxemia. The two factors are not related. An increased severity of shock does not increase the infection, and the infection in turn does not increase the shock. These two factors are separate.

Regarding the paper of Drs. Blocker et al., data on what the casualties were doing (on the battlefield or in the city), when they were hit, what happened to them later from a multiplicity of injuries, when they died and what they died of are difficult to find in current medical military statistics. Speaking for myself, as a soldier, we owe a great debt to Dr. Blocker and his associates for these follow-up studies and for the original study. My personal experience in Texas City was in another hospital, not in John Sealy. As I recall, the biggest problem we had was keeping records, knowing who got what and when and where they went.

I personally would like to acknowledge a great debt on the part of the military to Dr. Blocker and his co-workers for maintaining some precious records through difficult circumstances.

JOHN M. HOWARD (closing): It is a pleasure to comment on Col. Lindsey's paper. I should like to mention a study that Dr. Artz and others plus myself conducted in Korea. When we took single biopsy specimens of wounds in military personnel we found (in a series of 100 casualties) an incidence of 40 per cent clostridia in that tiny bit of the wound. When we took multiple biopsies from the wounds, the incidence went up to about 80 per cent. Following débridement, the clostridia were still immediately afterward but serial biopsies on the third, fifth, seventh, and ninth days demonstrated that gradually the clostridia disappeared from the débrided wound unless necrotic tissue remained.

Col. Lindsey has made the point that débridement is effective. The significance of continuation of this work, in my opinion, lies first with the mass casualty problem when débridement will not be possible, and second, in the many problems of infection such as intra-abdominal injury or mesenteric thrombosis when we may not have fully recognized the importance of infection.

I should like to mention one other thing about Col. Lindsey's paper. We took scores of cultures of soil, and perfringens was present in every culture taken from the mountainsides, the valleys and the camps.

Dr. Casberg and his associates have presented a facet of the problem of the work under way in the heat treatment of plasma. As you know, this gained part of its impetus from Philadelphia where room storage and elevated temperature storage over long periods of time seemed effective. Many investigators are at present studying the effect of heating plasma to 60°C. for approximately ten hours. It has the effect of precipitating or destroying fibrinogen and to varying degrees other plasma proteins. There are other problems to be worked out such as the formation of large protein particles and the possible immunological reactions. There are several other similar products under evaluation.

As to the problems of dextran and dextran stockpiling, it is always healthy to have a critic challenge the basic premises on which action is being taken. Let me assure you that those who have gone into this have gone into it thoughtfully, and with a scientific and clinical basis now of literally hundreds of studies in animals, toxicity studies, blood volume studies and clinical effectiveness in humans.

As to correlating dextran with saline, in Dr. Cournand's study of dextran and dextran in saline it was revealed that after 1,000 ml. the blood volume increment in one hour was 800 ml. and in twelve hours, 450 ml. It should also be pointed out that this has been found when gelatin or PVP was used. Furthermore, when you reduce the molecular weight of dextran to 35,000 it is excreted quite rapidly following administration. This is not so true of the larger molecular weight fractions. Even when both are suspended in saline, the large molecular weight preparation, because of its retention, results in a larger, more sustained blood volume increment. The same amount of saline existed in each.

I cannot answer Dr. Blunt's question regarding the fate of the dextran manufactured a number of years ago. Someone has asked how much dextran should be used. The answer is that we should hope not to use any. We should prefer to use blood or

plasma. However, the decision is relative to the immediate needs under the urgent situations in which you may find yourself. As a clinical guide, let me say 2 units (1,000 ml. total) is a safe, conservative range.

Few evidences of toxicity, few evidences of bleeding and few evidences of anoxia from a low hematocrit will be detected if one confines himself to 1, 2 or perhaps slightly greater volumes.

TRUMAN G. BLOCKER, JR. (closing): There were approximately fifteen cases of clinical gas gangrene in the 850-odd patients hospitalized after the Texas City disaster. Four of these patients died within twenty-four to forty-eight hours with very severe, multiple wounds but not from gas gangrene. The gas gangrene was found at the autopsy table in a localized area.

Seven of the eleven patients survived after amputation (six operations involved the lower extremities) and other extensive débridement procedures.

A large number of wounds were cultured as the perfringens organisms were found, and all patients with a positive result received 1 million units of penicillin intravenously and 500,000 units intravenously every four to six hours afterward. At that time the standard dose of penicillin was in the neighborhood of 15,000 units every six hours.

All the patients who had positive perfringens organisms obtained from their wound underwent thorough débridement. I feel certain that many of us believed the antitoxin given to these patients as a prophylactic was ineffectual, but that the débridement was the important thing in that instance.

Concerning dextran and heat-treated plasma, I have the reports of Drs. Howard and Artz about their work in the hospital in Korea. When I visited them during the conflict in Korea they had such a well set-up laboratory and such a well controlled study that I feel certain they proved beyond a shadow of a doubt that dextran is an important plasma expander. I feel we should have some method of immediate production of this material if there is a possibility of war.

At the present time there is very little dextran used in this country and I have been told—I do not know how true it is—that with the stockpile we have and at the present rate of usage of dextran, it would take us fifty years to use it all. However, as far as I can see, that does not prevent the continued use of this material as a potential useful plasma expander if we are potentially at war.

There were two notable changes in the pattern of injury that we found in the Texas City disaster in this recent survey. First, there were very few residual effects of internal blast injuries observed by the examining group. Second, 43 per cent of the patients examined reported symptoms suggesting functional disturbances which were blamed upon physical or psychological results of the Texas City disaster, such as headaches, nervousness, weakness, inability to think clearly, difficulty in working, insomnia, bad dreams, back pain, indigestion, poor appetite, dizziness, palpitation and so forth. All those psychoneuroses were diagnosed in only 8 per cent of the patients given a permanent partial disability rating. In a small number of cases functional complaints contributed greatly to the period of temporary total disability for which compensation was made and interfered considerably with the accurate appraisal of residual impairments.

Albert G. Walter

NINETEENTH CENTURY PITTSBURGH PIONEER IN THE SURGERY OF TRAUMA

WALTER SCOTT NETTROUR, M.D., *Pittsburgh, Pennsylvania*

ALBERT G. WALTER must be accorded a place of distinction as a pioneer in the surgery of trauma.

Not only was he a fine surgeon who saw the great need and importance of the study of injuries but he maintained excellent records and published forty-two articles in leading medical journals. He also published two books* "Fractures of Bone" and "Conservative Surgery," but, even more important, he stressed such fundamental principles as cleanliness and fresh air as important factors in surgery.

Dr. Walter was born in Germany in 1811. He was orphaned at the age of four. His medical education consisted of a Doctor of Medicine degree from Köenigsburgh and a year's postgraduate work in surgery at Berlin under the celebrated Dieffenbach.

Walter's plans of emigrating to America were interrupted by a shipwreck off the coast of Norway with the loss of all his personal possessions. He worked in London for a year as a clerk in a law office to obtain money to continue his trip. During his enforced stay in London he attended medical lectures and profited by those of Sir Astley Cooper.

On arrival in New York City and later in Philadelphia, Walter found the medical profession unsympathetic; "there was no room for a Dutchman." After practicing two years in Nashville, Tennessee, Walter came to Pittsburgh in 1837 where he remained in active practice until his death in 1876. From the early days of his Pittsburgh career, Walter secured accident work from the mills and his superiority to other surgeons who did such work was so quickly apparent that he soon acquired a national reputation for accident surgery.

Walter was a persevering student. He worked industriously through the day and sat up until the small hours of the night making notes and devising mechanical methods of accident treatment.

In these early times Walter divided and corrected tendons and performed arthroplastic operations on the femur, vertebra and joints. The Museum of the Medical School of the University of Pittsburgh has many of his casts recording the deformed limbs before and after treatment and they bear silent testimony to his skill, consuming energy and unbounded enthusiasm. Although he excelled in traumatic orthopedic correction of bone injuries, two of his most prominent cases were related to soft tissue injury. One was a life-saving tracheotomy in a case of obstructing laryngeal diphtheria. The other was the first successful case report of recovery following repair of a urinary bladder. This latter was published in the Medical and Surgical Reporter of November 16, 1861.

In these early times, Walter advocated the use of silver plates in open fixation of fractures and the removal of devitalized tissue; he stressed the importance of Nature's salvation in healing which "has alas! been too often either overlooked, or plainly misunderstood." After repeatedly cautioning the need of cleanliness in surgery, he stressed that "pure air is not only harmless but priceless to man and all the rest of creation, whether in a healthy or an afflicted condition."

His clear thinking was well adjusted to accept the work of Joseph Lister of Glasgow, and Pasteur's theory of minute organisms. Although the theory of germs floating in air was supported by James Symes and other eminent European authorities, Walter argued against the carbolic acid spray. He argued not against the germ theory but against the method of combating

* Referred to in: DILLER, T. Pioneer Medicine in Western Pennsylvania. New York, 1927. Paul B. Hoeber, Inc.

the germs, and he was again ahead of his time in arguing for the great value of sunshine and fresh air and cleanliness.

Unfortunately, this man of fierce courage spoke with the utmost candor about his colleagues and his case reports are full of pungent criticisms of his fellow surgeons. He was involved in many law suits both of his own and against others, and his personal life was tumultuous and tempestuous.

Walter was very devoted to his family and was one of the founders (1874) and the first Chairman of the Humane Society of Pittsburgh, and his love of animals and children were "commands of the heart."

Dr. Walter was a genius of remarkable talent and marvelous industry. His love for surgery and his ability to perform it well added to his careful records. His publications made him a great beacon light in the surgery of trauma in the United States. Unfortunately, his criticism, egotism and lack of leadership may have retarded the spread of some of his work in the profession.

Albert G. Walter's legacy to suffering humanity is attested to by the titles and dates of his published works.

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2. Hydrocele of the tunic vaginalis: haematocele; effusion of serum into the cellular tissue of the scrotum and penis. *Brit. M. J.*, p. 524, 1857.
3. Lithotomy by the medio-perineal section: with cases. *Brit. M. J.*, p. 1006, 1857.
4. Removal of the entire body of the scapula for sarcomatous degeneration of its structure. *Brit. M. J.*, p. 225, 1858.
5. Plastic operation for the relief of structural contraction from a burn. *Brit. M. J.*, p. 263, 1858.
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7. Rhinoplastic operations. *M. & S. Reporter*, 2: 244, 1859.
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9. Excision of the os calcis and cuboideum; resection of the proximal extremity of the fifth os metatarsi and of the articulating surface of the astragalus for scrofulous caries of the astragalo-calcanean articulation. *M. & S. Reporter*, 3: 113, 1859.
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21. Tracheotomy for removal of a large copper cent impacted in the larynx. *Cincinnati M. & S. News*, 3: 78, 1862.
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First-Aid Equipment for Traffic Accidents

J. C. Dickison, M.D., C.M., F.R.C.S. (C), *Montreal, Canada*

One of the problems which confronts both the motoring public and the medical profession in North America is the inability to purchase a satisfactory first-aid equipment box to keep in the car. Although the equipment need not be expensive, I do believe it must be contained in a metal or plastic box, otherwise it would soon be destroyed if kept permanently anywhere in the modern car. In the past two years I have failed to interest two large dressing supply companies to produce a first-aid kit according to my recommendations. Both companies have estimated that the general public will not buy a unit which comes to the value of approximately $10.00 to $12.00.

If one goes into the average drugstore today and asks for a first-aid kit to keep in a car he would probably be shown the common type of kit which contains some band-aids, a few 1-inch gauze bandages, burn ointment, and a small bottle of iodine. (Fig. 1.) In most car accidents involving injury this equipment is useless. If this small kit is considered acceptable in the car, then the public is wasting its money and being misled.

In first-aid care the rules of any surgeon with experience in the handling of casualties are simple and may be listed as follows: (1) wounds should be well covered, (2) hemorrhage should be arrested, (3) broken limbs should be splinted, (4) antiseptics are quite unnecessary, and (5) general supportive care should be given the patient to insure an adequate airway, to keep him warm, and to relieve pain as much as possible.

In covering wounds the use of a large dressing to cover a small wound can be excused, but major compound fractures of the limbs demand a large dressing for their coverage. Therefore it is recommended that this kit (Fig. 2) contain half a dozen sterile dressings of about 6 by 8 inches in size. It is recommended that crepe bandages be used for their application to the wound. Even doctors have trouble trying to apply gauze bandages properly, and one has only to do some work in a casualty center to see how poorly cotton bandages are applied. Anybody can apply a crepe elastic bandage, firmly and securely.

A card of safety pins to fasten bandages is of course necessary and a small pair of scissors to cut away clothing where necessary.

In the splinting of fractures, four of the common triangular St. John's ambulance bandages cannot be improved upon. Any injury of the upper extremity, whether or not it can be recognized as a possible fracture, is best splinted by two slings, one a full-arm sling enclosing the forearm and the second fastening the upper arm to the body. In this way the splinting is performed by the body and is very secure.

For the lower extremity, slings and crepe bandages can be used to fasten one leg to the other or to an umbrella or any available rigid object. The use of these triangular bandages for injuries to the hands, feet and head need not be elaborated upon, as they are excellent for supporting a dressing.

It is well known that local pressure will arrest

Fig. 1.

FIG. 2.

hemorrhage in the majority of wounds. Local pressure with a clean dressing on the wound using one or more elastic crepe bandages has certainly proved successful in practically all wounds that I have treated. It has been stated that more limbs have been lost than saved by the use of a tourniquet, and with this point I agree. Unless a tourniquet is applied properly and with enough pressure to occlude the arterial pulse, it can cause profuse hemorrhage which would not have otherwise occurred.

In the first-aid box in my own car I have included a simple plastic airway. I have not had to use it yet but this simple gadget may be a lifesaving instrument at some time.

With the proper use of these materials (large sterile dressings, crepe bandages, and triangular bandages), one can confidently anticipate being able to handle any accidents in a satisfactory "first-aid" manner.

I think most surgeons will agree that the use of antiseptics in first-aid care is not only useless but may be harmful. In my opinion this is quite unnecessary when patients involved in traffic accidents are going to have early definitive care.

In summary, in my opinion, one problem in relation to car accidents could be solved by the production of a simple metal or plastic box containing the articles just mentioned, with simple line drawings illustrating the use of the triangular bandage. Even a few of the old "shell dressings" as used in the last war for covering major injuries, would prove to be a lot more useful than anything which is available on the market today for the general public.

A New Plastic Prosthesis for Repairing Tissue Defects of the Chest and Abdominal Wall

FRANCIS C. USHER, M.D., *Houston, Texas*

THERE has always been the need for a suitable prosthesis for replacing large defects of the chest and abdominal wall which cannot be closed by utilization of the tissues at hand. Such defects may be created by traumatic avulsion of portions of the abdominal or chest wall due to missiles, or by loss of substance due to later infection and necrosis. Resection of tumors of the chest wall and abdominal wall frequently result in large defects. Large incisional hernias are often best repaired with some type of space-filling prosthesis.

For this purpose autogenous fascial flaps, both free [*14*] and pedicled [*19*], have been used. Split-thickness skin grafts [*4,5*] have been used rather extensively in the past ten years. Homografts of fascia lata [*15*] and dura mater [*16*] have been tried. Since all these grafts are animal tissues, they have the disadvantage of being subject to dissolution in the host tissues and breakdown of the repair.

Metallic meshes of tantalum [*7*] and stainless steel [*3*] have been quite popular, but objections have been raised to their use because of the fragmentation of the wire mesh that occurs within two to three months following implantation.

Synthetic fabrics of ivalon [*13*], fortisan [*9*], nylon [*1,2,10,11,21*], orlon [*12*] and dacron [*20*] have been used, but all have been shown to be intolerant to infection, resulting in slough of the graft or necessitating its removal. The metallic meshes are superior in this respect: they are inert in the presence of infection [*8*].

Fabrics of teflon [*6*] have also been used experimentally in dogs, and are reported to be resistant to infection. The fabric cannot be calendered, however, and the more open weaves tend to be shoddy and ravel easily.

Marlex* possesses physical properties making it desirable for use as a surgical prosthesis. It is chemically inert, being highly resistant to acids, alkalies and most organic solvents. It is non-wettable. It has high tensile strength (comparable to high-test nylon) when extruded as a monofilament.

We found that marlex had very little foreign body reaction when compared to nylon, orlon, and dacron [*18*]. It was comparable to teflon in its biological inertness.

EXPERIMENTAL STUDIES

A mesh was then woven from the monofilament with a thread count of 42 by 42 to the inch. (Fig. 1.) This mesh had the desired porosity for fibroplasia and also possessed the stability of fiber and tensile strength necessary for a satisfactory tissue replacement prosthesis. Experiments were then performed on dogs to evaluate it as a replacement for defects of the diaphragm, chest wall, and abdominal wall [*17*]. A satisfactory growth of fibrous tissue through the mesh was found to take place in about six weeks following implantation of the prosthesis. This layer of fibrous tissue was quite uniform in all the dogs [*15*], was pliable and about 4 to 5 mm. in thickness. There was no increase in the amount of fibrous tissue replacement after six weeks.

Ten dogs were used in a study to determine the reaction of tissues to marlex mesh in the presence of infection. We found that suppurative wounds, with proper drainage and the use of specific antibiotics, would heal by secondary intention with the prosthesis in place. Granulating tissue was observed to grow

* Trade name of Phillips Chemical Company's new high-density polyethylene.

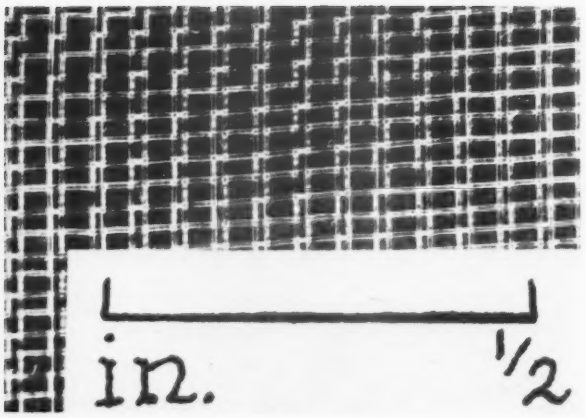

FIG. 1. Low power magnification of marlex mesh, showing taffeta weave.

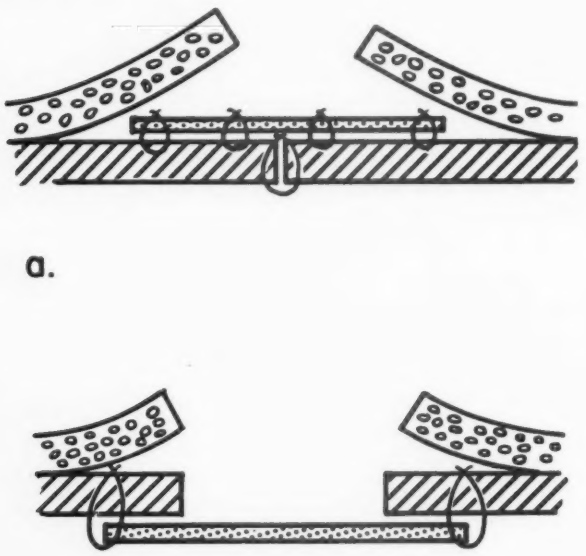

FIG. 2. Diagrams showing technique of (a) reinforcement of approximated fascial tissues, and (b) subfascial implantation of the mesh to bridge a tissue defect.

through the mesh followed by complete healing of the wound. In all ten dogs the wounds healed without complication.

Having obtained such favorable results in our experimental investigation of the marlex mesh, we next considered its clinical application. We used it at first as a reinforcing material to strengthen approximated tissues in the repair of large incisional hernias. (Fig. 2.)

METHODS OF REPAIR

For the repair of an incisional hernia, a long skin incision was made to provide good exposure. The hernial sac was left intact while the subcutaneous fat was dissected from the anterior fascia for a distance of 5 cm. from the hernial ring in all directions. Care was taken to obtain complete hemostasis. The hernial sac was then opened and after releasing any adhesions of bowel or omentum, was completely excised. The edges of the hernial ring were dissected free of any remaining properitoneal fat. These edges were then approximated with interrupted sutures of No. 000 multifilament steel wire. By placing all of these sutures before tying, we found there was less tendency for individual sutures to "cut through." A strip of marlex mesh 7.5 to 10 cm. in width was then sutured over the repair, using No. 000 multifilament steel wire interrupted sutures. One edge of the mesh was sutured down first in order that the opposing edge could be sutured under tension. Basting stitches were taken through the middle of the marlex implant to prevent buckling. Two fenestrated No. 18 French catheters were placed on either side of the completed repair for suction drainage. The subcutaneous tissues were closed with interrupted sutures of No. 00 plain catgut. In placing these sutures, the needle was passed through the mesh to include a "bite" of the underlying anterior fascia. These sutures approximated subcutaneous fat to the marlex implant and helped to eliminate dead space. A pressure dressing of mechanic's waste and elastic tape was applied after the skin closure.

Having noted in our experimental work that in dogs in which the entire abdominal wall had been replaced with the mesh there was a strong and satisfactory fibrous tissue replacement, we then applied this technique of repair to clinical cases. In those incisional hernias in which the opposing edges of the hernial ring could not be approximated because of tension (according to the technique just described), we used the following method.

After adequate dissection and exposure of the hernial sac and surrounding anterior fascia, as described in the first method, the hernial sac was completely excised. The peritoneum was incised at its point of fusion with other fascial layers at the hernial ring for the entire circumference of this structure. It was then dissected away, along with properitoneal fat, for a distance of about 3 to 4 cm. from the edge of the ring, exposing transversalis fascia (or rectus muscle, in the case of lower midline

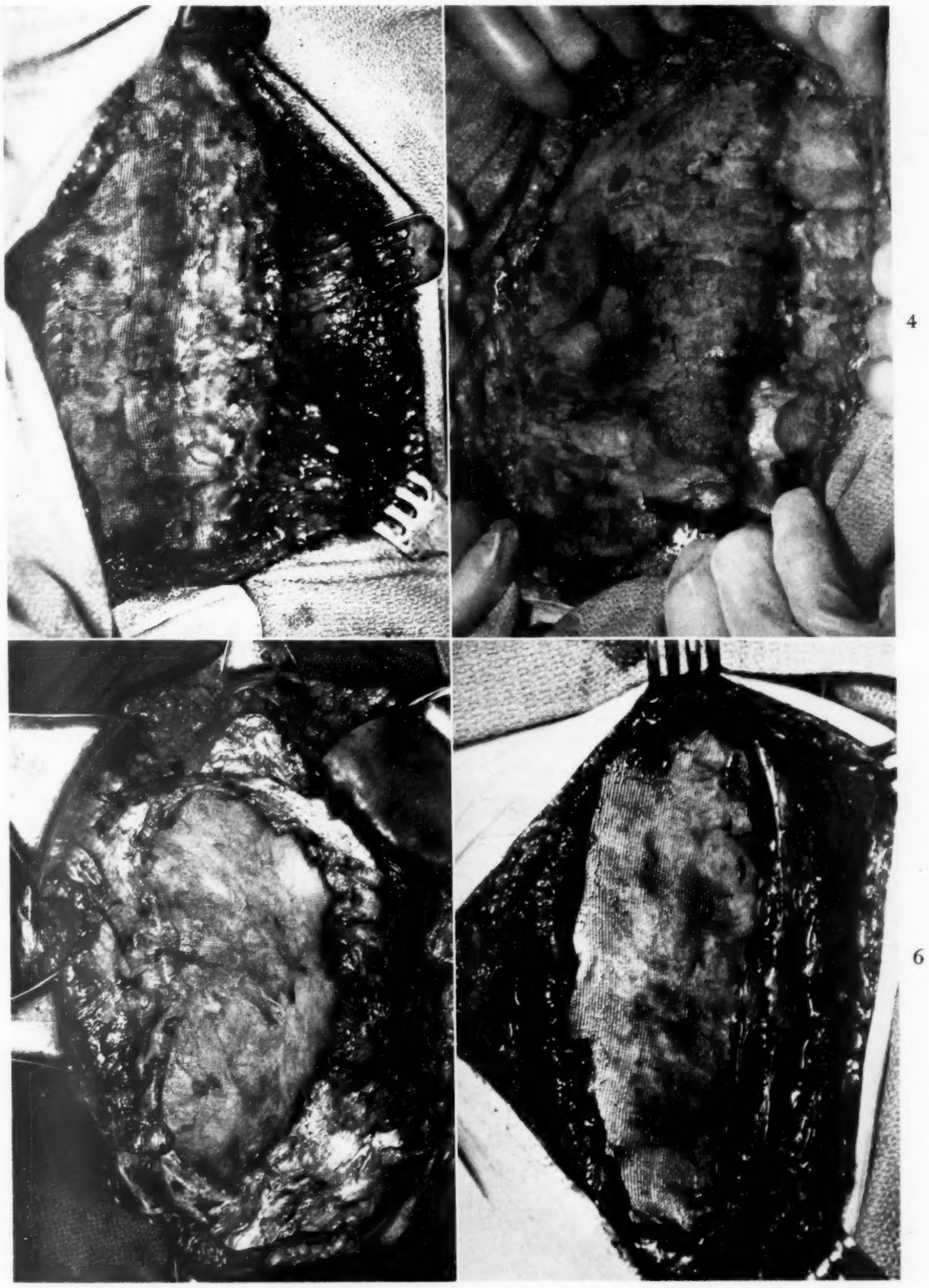

Fig. 3. Upper midline incisional hernia repaired by approximation of fascial tissues and reinforcement with marlex mesh.

Fig. 4. Lower midline incisional hernia repaired by approximation of fascial tissues and reinforcement with marlex mesh.

Fig. 5. Lower midline incisional hernia repaired by subfascial implantation of marlex mesh.

Fig. 6. Defect of abdominal wall (mid-abdomen) resulting from excision of metastatic carcinoma of abdominal wall. Repaired by subfascial implantation of marlex mesh.

hernias). The marlex mesh, cut to the proper pattern and the edges sealed by heat, was then sutured to the undersurface of the abdominal wall, using interrupted through and through mattress sutures of No. 0 black silk. First one row of mattress sutures was placed and tied, then sutures were placed and tagged on the opposing side, the second row being placed so as to produce a moderate tension on the mesh when tied. By placing all of the opposing row of sutures before tying, tension was more evenly distributed among the sutures and the procedure more easily accomplished. Finally, mattress sutures were placed to close the upper and lower ends of the graft. Before placing the second row of sutures, the omentum, when possible, was stretched out so as to cover the under surface of the mesh; it clung quite tenaciously to the graft and required no sutures to hold it in place. Two or more catheter drains were placed over the mesh for continuous suction drainage. The skin and subcutaneous tissues were then sutured directly over the mesh, but no attempt was made to suture subcutaneous tissues to the mesh itself. A pressure dressing was applied after the skin closure.

RESULTS

Forty-four patients with incisional hernias were operated upon according to the technique first described. (Figs. 3 and 4.) They have been followed up for periods of one to fourteen months. There have been no recurrences. In eight patients postoperative serum collections developed over the mesh. Simple aspiration resulted in disappearance of the serum and complete wound healing in three patients; in the other five, wound infections developed. The wounds of these five patients healed following adequate incision and drainage (silk sutures were removed from three of the infected wounds) and the use of the specific antibiotic. In none of the infected wounds was it necessary to remove the marlex mesh.

The second technique described, in which the mesh is sutured to the inner aspect of the abdominal or chest wall was used in a group of fifteen patients (Figs. 5 and 6.) Seven of these patients had large incisional hernias, three had defects of the abdominal wall due to excision of tumors of the abdominal wall, and five had defects in the chest wall secondary to excision of tumors of the ribs. Follow-up studies range from one to eleven months and the repair in all fifteen cases has been quite satisfactory. There have been no recurrences. In two of the incisional hernias postoperative wound infections developed, both of which healed completely following incision and drainage and use of the specific antibiotic. It is our impression that serum collections occur less frequently when the mesh is sutured to the inner aspect of the abdominal or chest wall, and for this reason we do not hesitate to use silk sutures for this technique whereas we recommend only wire for subcutaneous implantation of the mesh.

SUMMARY

A suitable mesh has been prepared from marlex, a new high-density polyethylene, which causes little foreign body reaction and is inert in the presence of infection. Experimental studies in dogs have shown that the mesh becomes infiltrated with a thin, pliable layer of fibrous tissue when used to replace defects of the abdominal wall, chest wall, and diaphragm. Wounds that had been purposely infected in dogs in which the marlex mesh had been implanted, healed by secondary intention, without draining sinuses or slough of the mesh.

Two techniques have been described for using the mesh to repair incisional hernias and other large defects of the abdominal wall, chest wall and diaphragm.

Marlex mesh has been used to repair tissue defects in fifty-nine patients with no recurrences to date. Wound complications have been few, and in no instance has the mesh had to be removed because of infection.

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Management of Intertrochanteric Fractures of the Femur

PRESTON A. WADE, M.D., *New York, New York,* ROLLA D. CAMPBELL, JR., M.D., *New York, New York,* AND ROBERT J. KERIN, M.D., *Milford, Connecticut*

INTERTROCHANTERIC fractures of the femur have been reviewed on the Combined Fracture Service of the New York Hospital and Hospital for Special Surgery at the Cornell University Medical School in an effort to evaluate the various methods of treatment in use since 1950. Altogether 183 cases have been studied, which includes all those patients treated in the eight and a half year period preceding July, 1958. Only thirteen patients did not receive operative treatment and some form of internal fixation. Although the largest group was that in which the Lorenzo screw and plate were used, this method of fixation has for the most part been given up on our service and preference developed for the Jewett single piece nail-plate appliance. The reasons for this change of surgical taste will be presented. Also, some words of caution will be added in regard to the technique of use of the Jewett nail-plate for the benefit of those who might thus be spared the same mistakes.

STATISTICAL DATA

Reasons for Non-operative Management. Of the thirteen patients not operated upon or receiving internal fixation, the reasons for non-operative management included: (1) the fracture was undisplaced, (2) often the patient did not get to the hospital until two or three weeks after injury, or (3) there were severe concomitant medical illnesses precluding surgery.

One death occurred in this group due to coronary occlusion three weeks after discontinuation of the six weeks of traction.

Sex, Race and Age; Side of Injury. Of the 170 surgical patients, there were three times more women than men (124 to 46, respectively). All but one of the patients were white. The average age was seventy-two, the youngest being twenty-nine and the oldest ninety-three. The following age groupings were found: Three patients were below the age of forty; five patients between forty and fifty; eighteen between fifty and sixty; thirty-five between sixty and seventy; fifty-nine between seventy and eighty; forty-three between eighty and ninety; and seven over the age of ninety. The left hip was involved ninety-two times, the right hip seventy-eight times.

Classification of Patients and Fractures. Seventy-eight patients were private cases and ninety-two were admitted to the service or ward. One hundred three of the fractures were displaced and required reduction; forty-eight were undisplaced. Fractures strictly of the base of the neck were eliminated, when clearly defined, as were subtrochanteric fractures. In nineteen instances some of the x-ray films were missing and could not be classified. There were no open fractures.

Type of Internal Fixation. The following variety of internal fixation devices was employed: Lorenzo screw only, one; Neufeld apparatus, two; other blade-plate, two; Thornton nail-plate, three; Smith-Petersen nail and McLaughlin plate, six; Jewett nail-plate, forty-seven; and the Lorenzo screw and plate, 110. This total includes three cases requiring replacement of the Lorenzo equipment by the Jewett nail-plate.

Antibiotics and Infections. One hundred-thirty-nine patients received some form of antibiotic therapy, the most commonly used preparation being Combiotic,® containing dihydrostreptomycin 0.5 gm. and penicillin 400,000 units combined in one ampul for parenteral injection. There were seven wound infections, including one case of gas gangrene, and all but one occurred in patients receiving antibiotics

postoperatively. One infection could not be controlled without resection of the head and neck of the femur. Except for five instances of hematoma requiring drainage, all other patients had *per primam* healing of their wounds.

Complications Unrelated to the Type of Internal Fixation. Complications appeared in over one-half the total number of patients operated upon, and one patient often exhibited more than one complication. These are listed as follows and do not include mechanical problems of internal fixation: wound infection, five; osteomyelitis, three; thrombophlebitis alone, four; thrombophlebitis with pulmonary embolus, four; decubiti, fifteen; pneumonia, six; urinary infection and/or retention, twenty-six; cerebrovascular accident, three; cerebral dementia, severe, three; coronary occlusion, two; allergic reaction to penicillin, two; intractable hiccoughs, one; acute glaucoma, one; auricular fibrillation, two; paralytic ileus, three; gastrointestinal hemorrhage, two; hematoma in wound, five; incarcerated femoral hernia, one; cholecystitis, two; pulmonary tuberculosis, one; furunculosis, one; postoperative acidosis, one.

Deaths. Thirteen deaths in a series of 170 surgically treated patients produced a mortality rate of 7 per cent which is accounted for as follows:

The intertrochanteric fracture of an eighty-three year old white woman was poorly reduced and a malplaced Smith-Petersen nail inserted which extruded out of the head posteriorly. The next day the nail and plate and fracture fragments disengaged, and under local anesthesia another nailing was accomplished. The first procedure took two hours and forty minutes; the second was carried out the next day in one hour and fifty minutes. The patient died rather suddenly three days after the second procedure, and the clinical impression was acute pulmonary embolism or myocardial infarction. Autopsy was not performed.

A sixty-eight year old woman had an uneventful fixation of an intertrochanteric fracture with the Lorenzo screw and plate. The duration of anesthesia was three hours under 1 per cent local N_2O. The patient had a febrile and toxic course postoperatively and was too ill to be helped out of bed and into a chair. Marked edema and crepitus of the wound and the involved thigh developed, and a diagnosis of gas gangrene was made. However, the gas bacillus was not demonstrated bacteriologically. Despite large doses of antibiotics and adequate drainage of the wound, the patient's condition went progressively downhill and she died on the eleventh postoperative day.

A ninety year old woman remained under anesthesia for five hours and thirty minutes because of a difficult reduction and operative procedure. She never recovered consciousness and died five hours postoperatively.

This sixty-seven year old woman with diabetic acidosis and congestive failure was prepared for surgery for two days; the diabetes was brought under control and she received digitalis. An uneventful two-hour procedure was carried out under 1 per cent local anesthesia. A few days postoperatively, with the diabetes under control and with no evidence of cardiac failure, she became comatose and died. Autopsy revealed bronchopneumonia and severe, advanced coronary artery disease. The cause of death was stated to be myocardial failure.

A ninety-three year old woman underwent an uneventful hip nailing of one hour and fifty minutes' duration under local 1 per cent procaine, Pentothal,® N_2O and O_2. On the first postoperative day the patient had an upper gastrointestinal hemorrhage and died of aspiration. Although it was not clinically apparent, autopsy revealed carcinoma of the head of the pancreas with extension to the liver, regional nodes and vertebrae. Sections of the fracture were taken, revealing no evidence of a pathological fracture. The neoplasm had eroded a blood vessel, causing the hemorrhage.

A sixty-eight year old white woman with an essentially undisplaced fracture underwent an uneventful nailing under Pentothal and N_2O, the duration of which was three hours and twenty minutes. On the third postoperative day the patient fell out of bed while reaching for a glass of water and died within the hour, apparently of an injury to the head.

An eighty-nine year old woman with a markedly displaced fracture underwent reduction and fixation under Pentothal, N_2O, O_2 and local anesthesia; the operation took two hours and twenty minutes. The patient died suddenly on the second postoperative day, and autopsy revealed the cause of death to be fat embolism to the lungs.

An essentially undisplaced fracture in an eighty-nine year old white man was internally fixed two and a half days after injury, under 1 per cent procaine anesthesia, in an operation lasting two hours and thirty minutes. On the third postoperative day the patient was noted to be acidotic

and uremic, his blood urea nitrogen rising to 115 mg. per cent. He died on the fifth postoperative day of renal failure, presumed to be on the basis of advanced vascular changes. Autopsy was not performed.

A seventy-five year old man, cachectic, with arteriosclerotic and hypertensive cardiovascular disease, had uneventful internal fixation of the involved hip two days after injury. On his first postoperative day he sat up in a chair but was lethargic. On the eighth postoperative day he became confused and disoriented. Urinary tract infection, bronchopneumonia and cardiac failure developed, and he died on the nineteenth postoperative day despite rigorous antibiotic therapy and digitalization. Autopsy was not performed.

A displaced fracture in a ninety year old woman could not be reduced, although several attempts were made to do so, in an operation requiring two hours under Pentothal, N_2O and O_2. An attempt was then made to fix the unreduced fracture internally. The fixation apparatus was malplaced in that it extruded from the femoral head posteriorly and traversed the hip joint. The patient was kept in bed for two months postoperatively, at which time there was collapse of the poorly held fragments and penetration of the Lorenzo screw into the pelvis. The patient died of pneumonitis and pulmonary embolism on the 242nd day of hospitalization. Autopsy was not performed.

A fifty-seven year old man with a pathological fracture from metastatic carcinoma of the eosphagus died three weeks after fixation with the Jewett nail-plate in spite of x-ray therapy.

This seventy-nine year old man, with arteriosclerotic heart disease, auricular fibrillation, senile mental changes, benign prostatic hypertrophy, chronic alcoholism, syphilis of the central nervous system and cirrhosis, underwent fixation of a severely unstable intertrochanteric fracture with the Jewett apparatus in a two-hour operation. Subsequently, repeated oozing of blood into the wound occurred which required readmission to the hospital, and this continued until the patient's death three months after the original fracture.

A seventy-five year old woman with a severely comminuted intertrochanteric fracture received excellent Jewett type fixation in three hours of surgery. Acute cholecystitis developed on the sixth postoperative day, requiring cholecystectomy. The patient died thirteen days after surgery of the gallbladder.

Varus Problems Related to Type of Internal Fixation. Thirty-one instances of postoperative development of a prominent varus deformity occurred in spite of initial satisfactory reduction. A small degree of coxa vara even up to 120 degrees, which represents a 15 degree deviation from an acceptable angle of 135 degrees, did not seem to be of importance. Once the coxa vara had become more pronounced, however, with angulation to 110 degrees or less, there usually was associated limp or pain. Significant varus developed after use of the various types of internal fixation in the following circumstances:

The Lorenzo screw and plate combination cut out of the head in five cases, usually from being improperly placed too superiorly in the neck or not deeply enough into the head, or both. In six patients there was bending or breaking of the plate-screw junction. (Fig. 1.) In twelve patients there was no apparent reason for the varus and it was thought to have been due to an inadequate supporting area of the screw in the neck and head. (Fig. 2.)

The Jewett apparatus was so poorly applied in four patients that the varus deformity subsequently appearing was regarded as inevitable. These were instances of the nail being placed too superiorly or not deeply enough.

The Thornton nail-plate combination proved too weak postoperatively in two cases, with bending and breakage of the nail-plate junction. (Fig. 3.)

There was inadequate securement of a Smith-Petersen nail to a McLaughlin plate in one patient, with varus following disengagement of the screw; this was in the right hip where the torque of external rotation would be expected to work the screw loose.

One blade-plate combination cut out of the neck in a severely unstable fracture in spite of satisfactory placement; arthroplasty using the Austin Moore prosthesis was performed for salvage. (Fig. 4.)

Problems of Hip Joint Penetration by Internal Fixation Equipment. The Lorenzo screw did not migrate into the acetabulum in two cases, but was initially overestimated in length so that it protruded far enough into the hip to produce significant mechanical problems. In each instance the operator was trying to hurry through surgery on a patient with a badly comminuted fracture who also represented a poor operative risk.

In seven cases, either at surgery or soon thereafter, the Jewett nail penetrated into the

FIG. 1. A sixty-four year old man was operated upon three days after injury. Duration of anesthesia was three hours. He was allowed out of bed the next day in a wheel chair and began to use crutches in the first week. Fifty per cent weight bearing was allowed at six weeks and the crutches were discarded at ten weeks. Only a fair result was obtained due to the development of significant varus in the first month from bending of the plate in spite of the fact that this man seemed to perform quite well with crutches.

hip. In three cases this occurred when the femoral shaft was displaced medially by the force of driving the nail into the neck in severely comminuted fractures which included complete separation of the shaft from the fragment of the greater trochanter. In four other cases the penetration developed inadvertently when the application of the nail through an intact shaft–greater trochaneter junction caused an additional fracture, separating the shaft from the greater trochanter with medial migration of the shaft and resultant excessive length

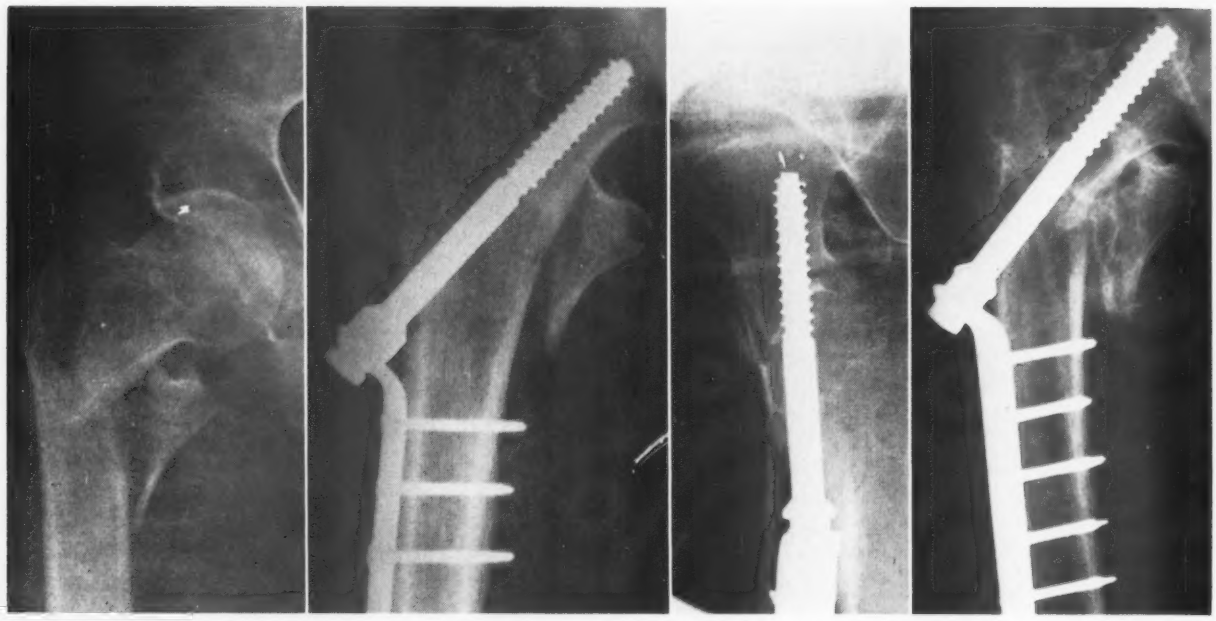

FIG. 2. A fifty-two year old woman was operated upon one day after injury. Duration of anesthesia was three and a half hours. She was in a wheel chair on the third postoperative day and allowed to use crutches in the first ten days. Although she had previously used crutches for the same leg and seemed quite capable of protecting the injured femur, significant varus developed in the first month with migration of the screw superiorly in the neck. Perhaps deeper fixation of the head would have helped to prevent this erosion.

FIG. 3. Intertrochanteric fracture in a seventy-eight year old woman was fixed by a Smith-Petersen nail and Thornton plate. Four months after operation the fixation screw broke, allowing fracture of the shaft at the site of insertion of the nail.

of a nail which previously had been correctly estimated in length. (Fig. 5.)

Follow-up and Evaluation of Function. In considering final rating, no case was included in which the follow-up was less than six months.

A good result was accorded when the patient was up and about walking with a cane, with minimal or no complaint of pain and minimal or no limp. The result of treatment was judged as only fair if the patient had pain and limp but was walking with or without a cane. Poor results included cases in which the patient had been ambulatory prior to the intertrochanteric fracture but could not walk postoperatively due to hip disability or could get about only with crutches. On these criteria the following ratings were found to apply to the Lorenzo and Jewett internal fixation methods, respectively:

Good: Lorenzo method, fifty of eighty-five; Jewett method, twenty-eight of thirty-nine.

Fair: Lorenzo method, twenty-four of eighty-five; Jewett method, eight of thirty-nine.

Poor: Lorenzo method, eleven of eighty-five; Jewett method, three of thirty-nine.

COMMENTS

There is no doubt that many of the intertrochanteric fractures encountered on any busy fracture service will be stable enough to be

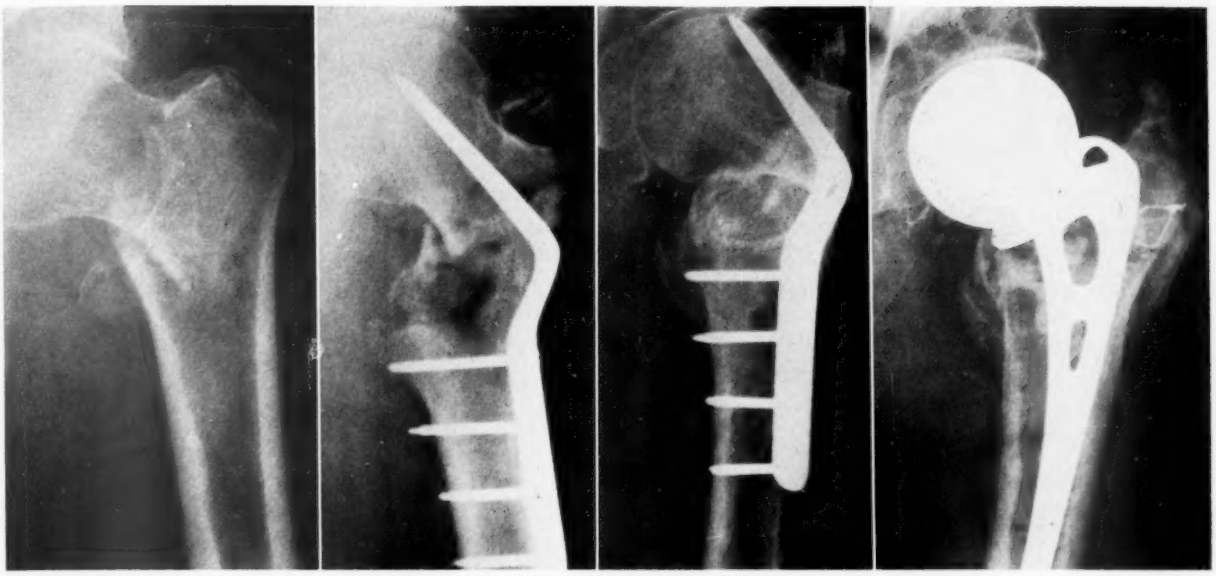

FIG. 4. A sixty-five year old man with a concomitant fracture of the humerus underwent open reduction of the intertrochanteric fracture three days after injury, under two hours and fifty minutes of anesthesia. Reduction was lost within ten days even while the patient was on a wheel chair regimen. Arthroplasty was performed after five months.

FIG. 5. This was an operative complication in a seventy-four year old man in whom open reduction was performed one day after admission but eight days after injury. The nail was angled in too much varus but a real problem came when in effort to gain impaction of the fracture the shaft was completely separated from the greater trochanter and shifted medially. This caused the nail to be relatively too long and it had to be replaced with a shorter one. Duration of anesthesia thus was four hours. Luckily a good result in healing and function was obtained at the second nailing.

FIG. 6. A fifty-two year old woman was operated upon three days after admission, under two and a half hours of anesthesia. This relatively stable fracture was adequately protected by weak internal fixation of the blade-plate. Wheel chair privileges were permitted on the first postoperative day, partial weight bearing in one month and full weight bearing at three months, with an excellent result.

managed without surgery or with a minimum of internal fixation to add strength across the fracture site. (Fig. 6.) In almost half the cases presented in this paper the fractures were undisplaced. Because of the advanced age of the majority of patients with intertrochanteric fractures, however, who have poor tolerance for the prolonged bedrest required by traction or weak internal fixation methods of treatment, there is urgent need to provide the strongest available apparatus to stabilize the fracture and allow early ambulation. It is our belief that open reduction should be deferred not more than twenty-four or forty-eight hours, which is usually long enough to allow medical evaluation and preparation of the patient.

The Lorenzo screw-plate combination is admittedly easier to apply than the fixed angle Jewett apparatus, and its employment in relatively stable fractures and with agile, cooperative patients who will be capable and faithful in the use of crutches has not been disappointing. (Fig. 7.) In more than one-quarter of the femurs receiving the Lorenzo apparatus, however, significant varus deformities developed.

In an effort to obtain better results from internal fixation of intertrochanteric fractures, the fixed angle Jewett nail-plate combination apparatus has been used almost without exception in the last fifty patients treated on this service, even in relatively stable fractures. (Fig. 8.) In less than one-tenth of this group significant varus deformities developed, and in these cases better use of the Jewett equipment could well have lowered the incidence. Although many of the patients were too senile to remember to try consistently to protect the fracture, or too weak or clumsy to manage crutches adequately until bone healing had occurred, there were no occasions of bending or breaking of the Jewett apparatus. The problems arising in the use of this equipment were, instead, those of technique of its application.

In this regard, two hazards have been recognized as distressingly recurrent. One has already been mentioned, namely, that of a disproportionately long relationship of the nail resulting from the femoral shaft being displaced medially either in the case of a comminuted fracture completely through the femur at the base of the greater trochanter, or in a relatively stable fracture which was rendered unstable by complete splitting off of the greater trochanter occurring in careless application of the nail through the cortex of the lateral shaft.

FIG. 7. A seventy-seven year old woman received open reduction and internal fixation in two and a half hours of anesthesia two days after injury. She was allowed slight weight bearing with a walker and then with crutches beginning on the sixth postoperative day, with full weight bearing at two months. A good anatomical and functional result was obtained in this cooperative, alert and well coordinated individual with an only moderately unstable fracture.

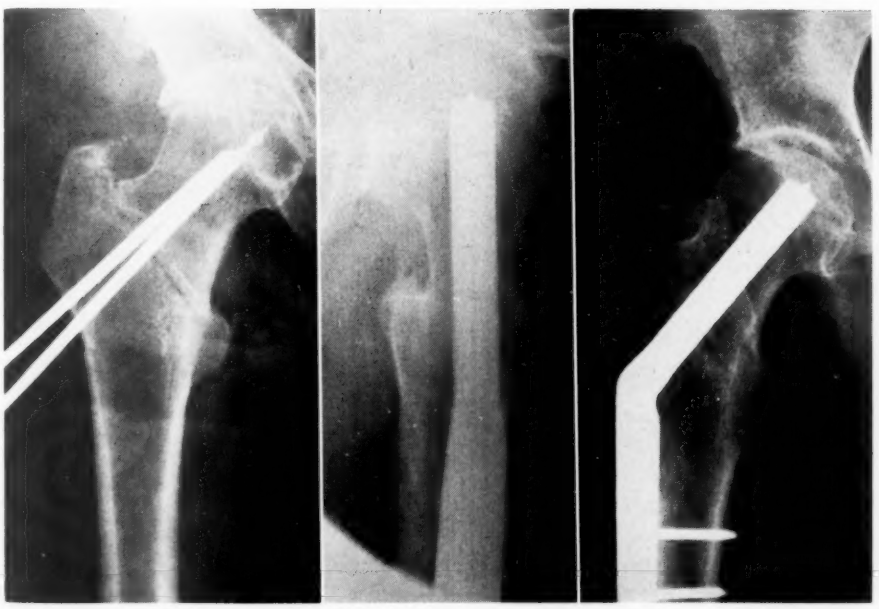

FIG. 8. This fifty-seven year old woman was admitted seven days post-injury after having been treated at another hospital with two Steinmann pins and a spica cast. Jewett nailing was done two days later, during a one and a half hour operation. The patient was allowed partial weight bearing with crutches at two weeks and full weight bearing at two months. An excellent result ensued.

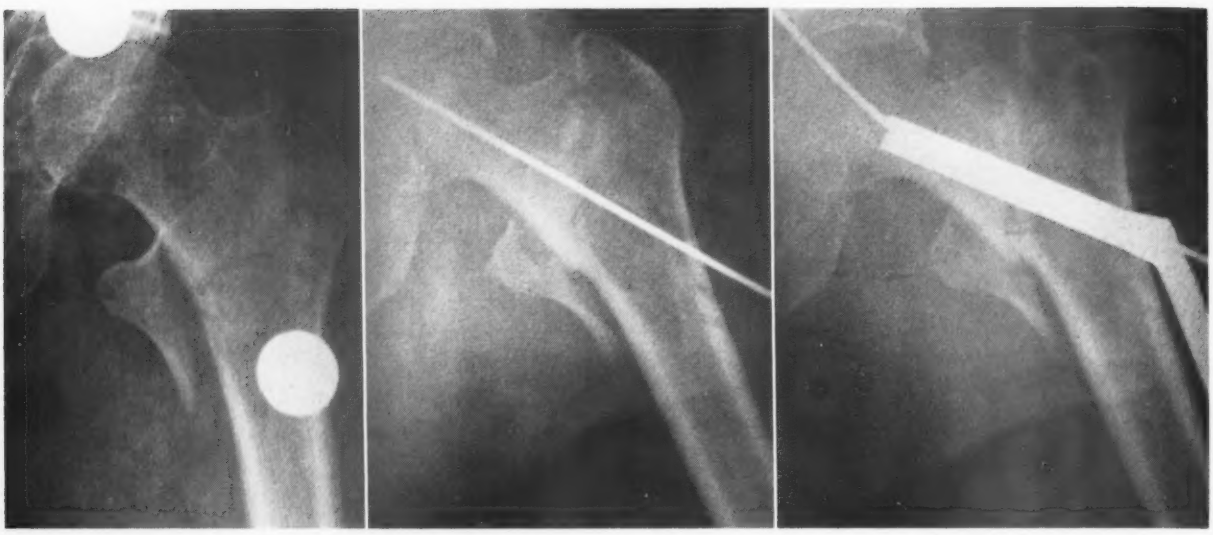

FIG. 9. An operative complication developed in this very obese seventy-four year old woman at surgery one day post-injury, when the lower end of the plate was pushed out by the soft tissue of the thigh, causing the nail to go into varus and to bend the guide wire. Fortunately this problem was recognized and corrected before the wire broke, but four hours of anesthesia were required. Satisfactory reduction was maintained but the patient required five months to graduate from the walker to crutches and was still using the latter at six months although the fracture was solidly healed.

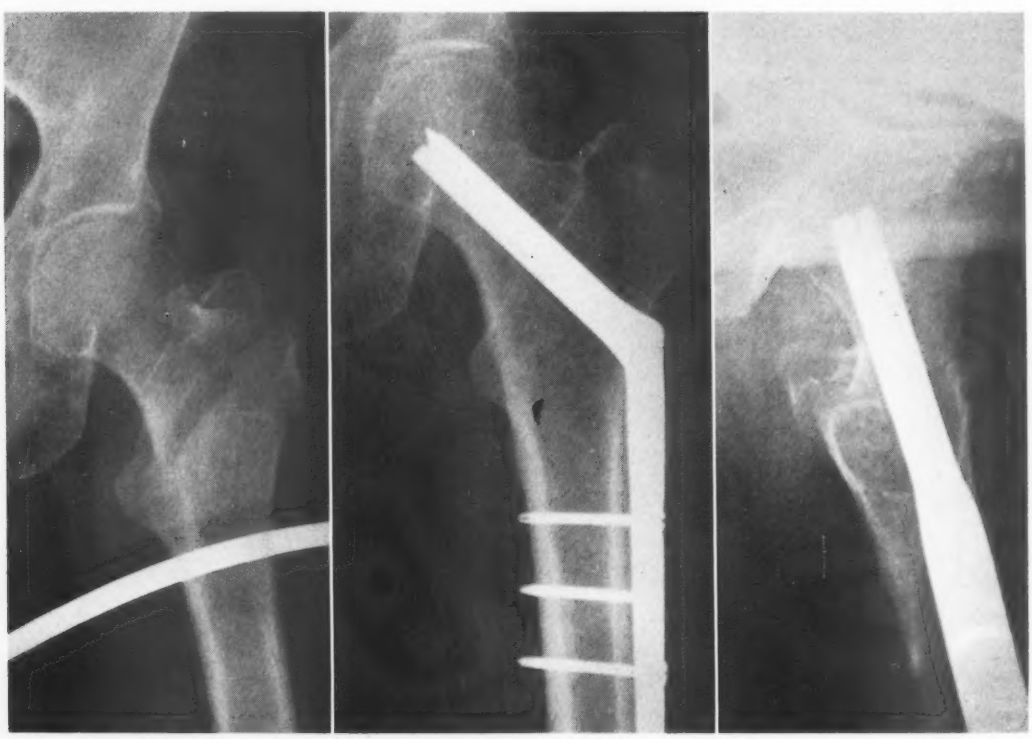

FIG. 10. A fifty-four year old man had Jewett fixation two days after injury, during two and a half hours of anesthesia. He was allowed partial weight bearing at one week and discarded crutches for a cane at six weeks, with a satisfactory anatomical and functional long term result. This is regarded as ideal Jewett nailing with penetration just to the middle of the femoral head and at the junction of the middle and posterior thirds of the head as seen in the lateral projection.

This point has previously been made in the literature by others [2,4,7]. Early or late penetration of the hip joint by the nail has not, however, been as permanent an aggravation to the patient as the varus problems encountered in the use of the Lorenzo apparatus which persist after removal of the internal fixation equipment [3,7].

The second technical hazard in using the Jewett solid nail-plate device has been the change in angle of application of the nail on the guide wire with the former being driven in more varus than the latter, with resultant bending or breaking of the guide pin. (Fig. 9.) This problem has been thought to be due to the fact that insufficient clearance had been made inferiorly for the plate through the soft tissue of the thigh, which had thus tilted the nail into varus.

Also, it must be recognized that if the nail is driven into the neck fragment in more valgus than the nail-plate angle, varus of the neck will be caused when the plate is attached to the lateral shaft. This problem was responsible for two of the four varus deformities resulting from poor application of the Jewett apparatus. The other two deformities were caused by too short a nail.

The length of the Jewett nail into the femoral head has been judged to be best placed if it reaches just to but not beyond the center of the head, where adequate support against the development of varus is obtained and yet sufficient space is left for deeper migration by the nail in compaction of the fracture site without penetration of the hip joint. (Fig. 10.)

CONCLUSIONS

Although very weak internal fixation may suffice to hold some relatively stable intertrochanteric fractures of the femur, the Lorenzo screw-plate combination device, blade-plates and attachable combination nail-plates, not including the new McLaughlin apparatus, have not proved as satisfactory in preventing varus deformity postoperatively in the more frequent unstable fractures as has the solid angle Jewett nail-plate apparatus. The latter is more difficult to apply technically, but the better results obtained make this extra effort worth while. There may be occasional need, in very unstable fractures, for an additional plate or hook from the top of the Jewett plate to buttress a loose greater trochanter and prevent overdrive of the nail.

SUMMARY

A review has been made of 183 intertrochanteric fractures which have been treated in an eight and a half year period on the Combined Fracture Service of the New York Hospital and the Hospital for Special Surgery at the Cornell University Medical School, in an effort to evaluate the various methods of treatment in use since 1950. All but thirteen patients received internal fixation.

Categories have been presented in regard to the reasons for non-operative management; sex, race and age of the surgical patients and the side injured; the amount of displacement of the fractures; the type of internal fixation devices employed; antibiotics and the incidence of infection; complications related and unrelated to the type of internal fixation used, the former including the occurrence of varus and penetration of the hip joint; and follow-up evaluations and a listing of the deaths.

Discussion has been directed at explanation of the reasons for failures and for the shift in preference generally from the Lorenzo screw-plate combination apparatus to the solid Jewett nail-plate. An effort has been made to outline the technical hazards which have arisen in use of the latter device.

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Pelvic Support Osteotomy for Certain Fracture Complications of the Hip

JAMES K. STACK, M.D. AND KONSTANTINE GEORGE, M.D., *Chicago, Illinois*

DURING recent years, prostheses for hip replacement have been widely used in an attempt to regain and maintain function of this joint. The prosthesis is usually employed as a last resort when unpredictable misfortune has rendered the local bone incapable of repair, or when the hip joint has been seriously impaired for other reasons. In the seventeen years since the introduction of this method of treatment, the combined experiences of many workers have brought about numerous improvements in its design and application. Although prostheses have gained in popularity among the many different types of reconstructive procedures, and more surgeons are familiar with their use, complications do occur. The failure of the prosthesis can be disastrous because a major portion of the head and neck of the femur must be removed to make way for it and little may be left for salvage. A serious quandary is thus set up.

FIG. 1. An end result. Flexion 90 degrees, extension 10 degrees, abduction 30 degrees, adduction 15 degrees, external rotation 35 degrees, internal rotation 10 degrees. The patient has a mild Trendelenburg sign and carries a cane when on the street, principally for balance.

In such a situation, consideration may be given to the resection-angulation osteotomy. (Fig. 1.) This operation is based upon the fact that the hip has as its function not only the forward movement of the leg but, more important, the support of the body above it. In walking, the extremity with the foot fixed on the ground supports the body and moves it forward. In doing this, the hip joint thrusts the body forward by extending the femur through the use of the powerful gluteal muscles. It raises the opposite side of the pelvis through the use of the abductors of the hip and rotates the pelvis about a perpendicular axis, thrusting the opposite side forward. The extremity which is off the ground is moved forward by the hip flexors. The importance of stability is demonstrated by the good function which a patient has with an ankylosed hip in a position of maximum function. The damaging effect of instability is noticed in patients with marked paralysis of the hip musculature, particularly in the gluteal muscles, and in cases of old, unreduced congenital dislocations or un-united fractures of the neck of the femur. We are all familiar with the waddling gait, the positive Trendelenburg sign and the tendency to throw the body forward in walking whenever the hip is unable to support the pelvis and the torso above it. The resection-angulation or pelvic support osteotomy has been advocated for many years in those instances in which hip dysfunction resulted from pathologic displacement of the mechanical axis without disturbance of the anatomic axis. Instability which is due to a loss or impairment of

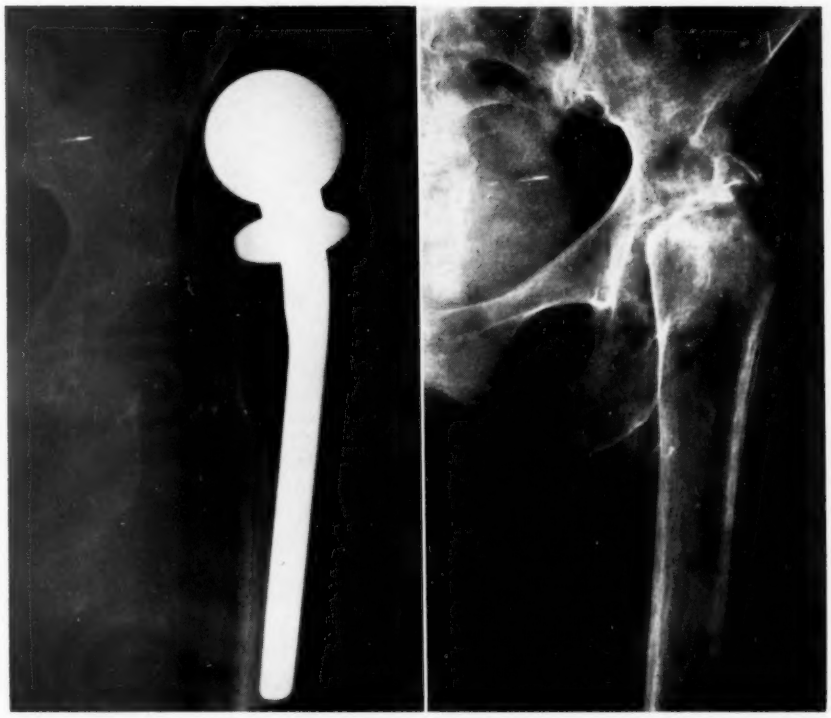

FIG. 2. This dislocation was about ten days old when first noted. Attempts at closed reduction are hazardous because of the danger of fracturing the osteoporotic femur. Such fractures can also occur in attempted open reduction. The arthroplasty seen on the right did not free the patient from pain and permitted such a small range of motion that no functional good came of it. Angulation-osteotomy would have been the treatment of choice. As a preliminary to such an operation in an instance of this kind, skeletal traction should be used to pull the femur down.

the normal anatomic fulcrum can be corrected by creating deformity in the anatomic axis. Classic osteotomies based upon this type of reconstructive mechanics were performed by Lorenz, von Baeyer and Schanz, and they were, of course, followed by some modifications. In seeking an operation which would satisfy the requirements of hip function, namely, comfort, mobility and stability, Milch in the United States [*5–10*], and Bachelor in England [*1*] popularized the resection-angulation procedure. By excising the femoral head and, thus, releasing the intra-articular obstructions, restoration of hip motion was accomplished and the subsequent instability was countered by the creation of femoral angulation. This caused a lateralization of the mechanical axis and achieved direct pelvic support. Each patient upon whom this operation was first performed had ankylosis of the hip secondary to (1) rheumatoid arthritis [*1*], and (2) tuberculosis [*9*]. The indication for the use of this method must be individualized and will be found in those instances in which arthrodesis or other types of arthroplasty are not indicated or have failed. The resection-angulation osteotomy has given favorable results in selected cases, i.e., arthrodesis, certain un-united fractures of the femoral neck with absorption of the neck and avascular necrosis of the head, and long-standing cases of congenital dislocation of the hip. (Figs. 2 and 3.) We believe that the indications may be enlarged to include certain patients whose hips have been replaced by stem prostheses and the end result has been a failure for one reason or another. (Figs. 4 through 7.)

In principle, the site of osteotomy for pelvic support is determined by the relationship of the femur to the acetabulum. The site of osteotomy is so placed that the transection of the bone and the remaining distal fragment fall under the acetabulum, thereby restoring a line of weight-bearing. This renders the hip more stable, and, at the same time, the femur proximal to the osteotomy acts as a lever for the function of the pelvifemoral muscles. All deformities present at

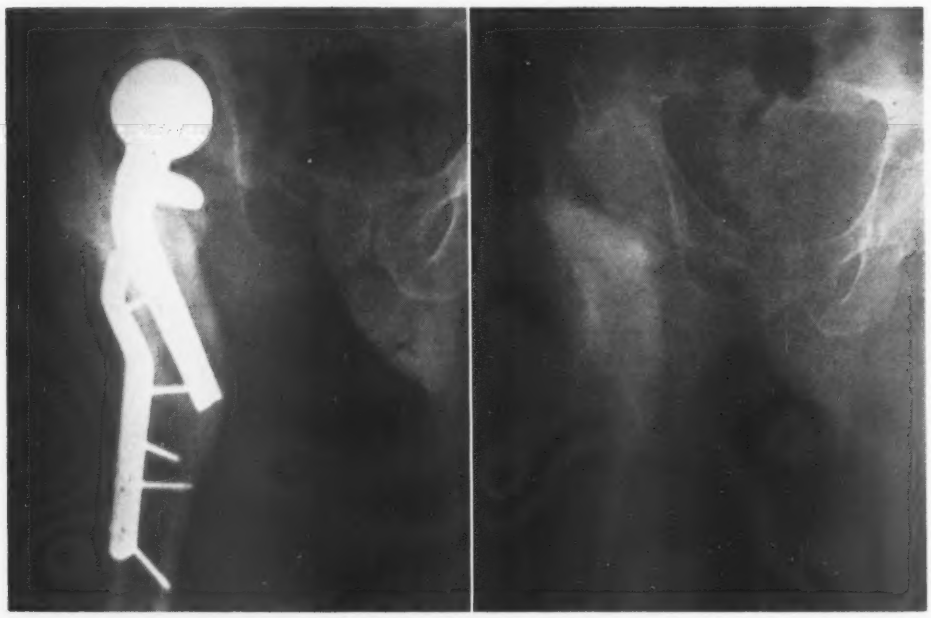

FIG. 3. This patient was greatly improved and able to return to his work following the removal of the hip prosthesis and the plate and screws. This illustrates the point that this patient, at least, was better off without a hip than with one. (Courtesy of Dr. F. N. Suma.)

FIG. 4. Note the "wandering acetabulum" and the intrapelvic intrusion of the metallic ball.

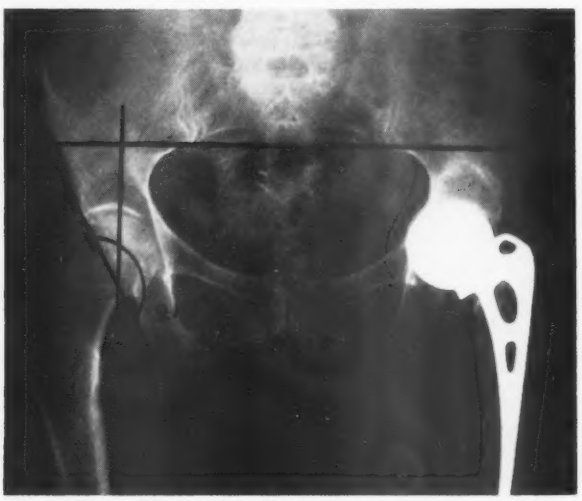

FIG. 5. Intrapelvic intrusion practically resulting in ankylosis.

the time of the operation (adduction, flexion and rotation) may be corrected by this method. The site of osteotomy, which has long been a controversial point, can simply be placed at a level where the osteotomy angle will come under the acetabulum. The improvement will be the result of the correction of deformities, the subsequent improvement in the function of the gluteal muscles, and, most of all, bringing the femur under the acetabulum where it can give the highest degree of stability.

As far back as 1838, Bouvier described subtrochanteric osteotomy in the treatment of congenital dislocations of the hip. Kirmisson in 1894 started a modern study of the subject and the development of the operation has continued since that time; however, in those early days, operative treatment of these conditions made relatively slow progress because sepsis was such a frequent complication of these open procedures. Lorenz, in 1919, Riedel, Dahs and Schwarz, Schumm, and Pauwels all made contributions to the general subject of osteotomy and the shifting of weight to allow for pelvic

support. McMurray, Haas and Ledbetter, Dixon, Ghormley, and Chatterton are other names associated with the development of this principle.

The two steps of the procedure, as indicated by its name are: (1) the resection of the head and neck, and (2) the creation of an angulation abduction deformity at the appropriate level in the femoral shaft. In those instances in which a prosthesis has failed, it is "resected," followed by osteotomy. The site of osteotomy and the degree of the postosteotomy angle will determine the deviation of the mechanical axis and the effective length of the limb. It is on these features that the functional result will depend. Although each situation will have some individual variation, emphasis is generally given to such factors as the inclination of the lateral pelvic wall, the amount of shortening, and the presence or absence of contractures. Inadequate degrees of angulation will lead to instability and a positive Trendelenburg sign, while an exaggerated angle is likely to cause reduction of mobility, pain and valgus deformity at the knee. The most favorable postosteotomy angle seems to be the one which is equal to the lateral tilt of the pelvic wall. This angle is approximately 205 to 215 degrees and can be met by producing a 30 to 35 degree abduction angle at the osteotomy site. This site is at a level in the

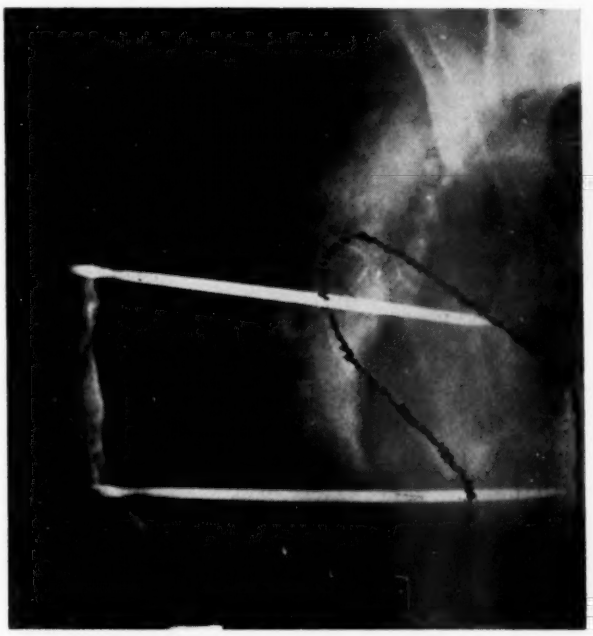

FIG. 6. The use of heavy pins in the proximal and distal fragments and their incorporation in the plaster hip spica.

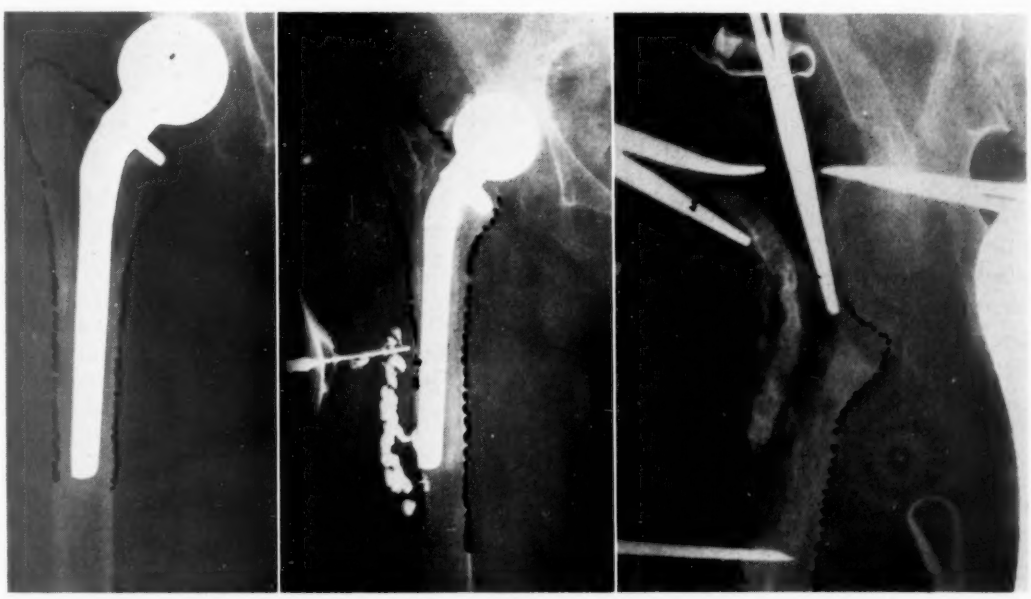

FIG. 7. *Left*, prosthesis inserted in the right hip of a fifty-four year old woman following the breaking of a Judet type prosthesis. This film was taken two years postoperatively. Note the wandering acetabulum and the erosion superiorly. *Middle*, note the continued erosion of the superior surface of the acetabulum and the settling of the collar of the prosthesis into the trochanteric area. The distal end of the stem of the prosthesis has worn through the lateral aspect of the femoral shaft to create a foreign body reaction and sinus formation. This is a lipiodol study of the sinus tract. *Right*, note the dispersion of the oil along the tract formerly occupied by the stem of the prosthesis. This film was taken in the operating room at the time osteotomy was performed. Note the chisel in the lower portion, depicting the osteotomy level.

subtrochanteric area which will provide an adequate proximal fragment so that its length, together with the angle, will result in a one-point fulcrum beneath the acetabulum. Because of the adduction of the proximal fragment the gluteal muscles regain their natural length and optimal physiomechanical relationships seem to be provided. The osteotomy, itself, can be stabilized by any of the internal fixation devices, or heavy pins may be placed in the upper and lower fragments and incorporated in the plaster of paris spica. The latter method has an advantage in that the osteotomy angle may be changed without reoperation in the early weeks of healing.

Five patients, aged fifty-one, fifty-seven, fifty-eight, sixty-two and fifty-four, have been subjected to this procedure since 1954. Their postoperative periods range from fourteen months to four years. Three are women who do not work outside the home, and the man is a watchman at a railroad crossing whose weight-bearing demands are not great. There is relative freedom from pain in all five patients and the requirement of hip flexion to 90 degrees to enable them to sit comfortably has been achieved. Two of the women still use a cane on the street; one woman uses a cane only after walking about a half mile, and the man no cane at all. Two of the women still have a positive Trendelenburg sign; one woman and the man have none. We believe that the presence of a slight Trendelenburg sign, or a gluteal limp is a small price to pay for the comfort and mobility that has been gained. It is interesting to note that the prosthetic failures presented here were all initiated by fractures in the femoral neck uncomplicated by arthritis. Such cases are generally considered to be the most promising for prosthetic replacement.

Bachelor says, "Excision-angulation osteotomy in young persons who have a reasonable chance of returning to active and useful life, and in older persons in whom the chief purpose is to allow them to sit in comfort and walk in their home is worthwhile."

In this era of the hip prosthesis, it seemed desirable to kindle an interest in this old operation to meet a new indication.

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Subtotal Anterior Lumbar Disc Excision and Vertebral Body Fusion

III. APPLICATION TO COMPLICATED AND RECURRENT MULTILEVEL DEGENERATIONS

PAUL H. HARMON, M.D., *San Francisco, California*

From the Department of Orthopedic Surgery, The Kaiser Foundation Hospital, San Francisco, California.

FOR the past eleven years I have been treating patients with radicular symptoms due to degeneration of the lower lumbar disc by an anterior extraperitoneal excisional operation [9] followed by vertebral body grafting. Many variations of operative technique, in regard to the operation itself and types of bone grafts, have been employed until the past three years when a highly standardized and simplified operative technique has been evolved.

This technique, described in detail elsewhere [10] but summarized in this paper, can be fully relied upon to (1) immediately and consistently relieve radicular pain, (2) abolish lumbago due to degeneration of the lower lumbar disc, and (3) stabilize the lower lumbar vertebral segments by sacralizing the lower two lumbar vertebral bodies (in a few instances the lower three lumbar bodies). The results improve with the passage of time, in comparison with the many results of excisional operations of the posterior fragmentary disc without fusion in which "recurrences" and "relapses" are frequently seen. Such undesirable later recurrences of radicular pain and prolonged recurrent bouts of lumbago vary from 10 to 15 per cent in the hands of the most adept surgeons with years of experience, to as high as 50 per cent in the hands of others.

Lane and Moore [16] were the first to publish an extensive series of cases in which two level anterior disc excisions were performed, and show that removal of the fourth and even the third lumbar disc was a feasible and safe surgical procedure. However, their transperitoneal approach was needlessly complex. Their report of end results concerned only the first eighteen postoperative months and the patients were governmental claimants. Gjessing [8] noted that he preferred anterior fusion to any type of posterior fusion in a small series of nine cases, and also demonstrated osseous union between vertebral bodies. While there are many workers, e.g., Adkins [2,3] who believe that vertebral body fusion cannot regularly succeed, it is certain from our results that failure is due to inadequate removal of the intervertebral fibrocartilages and employment of too small quantities of bone for grafting, two conditions that regularly lead to non-union from bone grafting at any site. Hult [13] described partial anterior disc excision without fusion (disc fenestration) and noted that although the operation was technically easy, many of the patients experienced "vertebral insufficiency," a state of weakness in the lower spine with variable lumbago. Fifteen months after operation only 70 per cent were back at work.

The modification of the anterior operation which we advocate and which relieves patients of both radicular and low back pain employs (1) an extraperitoneal hypogastric pararectus approach; (2) thorough and complete removal of the intervertebral disc(s) under direct vision; (3) excision of the cortical vertebral osseous plates; (4) forcible impaction of bone grafts to fill the entire space created by this excision while the spine is held in extension; (5) maintenance of vertebral spacing by good grade cortical and cancellous bone grafts without the necessity of using braces or casts for postoperative support. Further, (6) the patient suffers no shock with this operation because there is little blood lost; (7) early (first day)

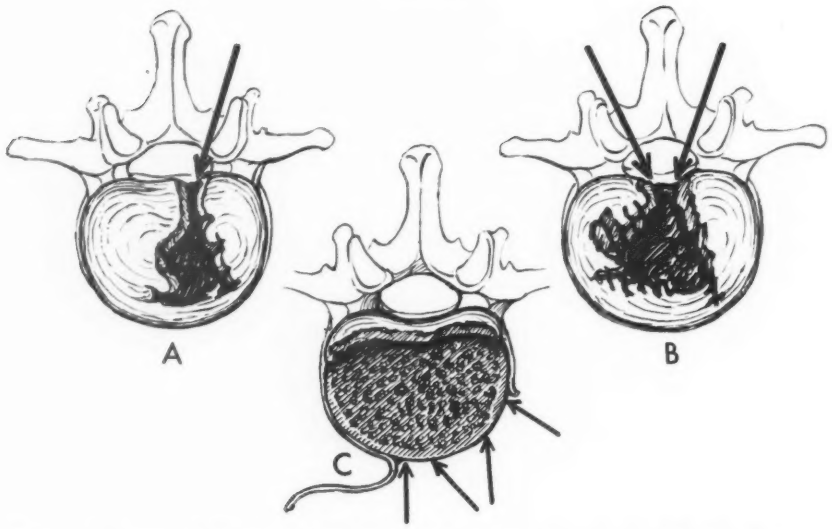


FIG. 1. Amount of fibrocartilage removable from the intervertebral disc from a posterior approach from a unilateral (A) and a bilateral (B) laminotomy exposure. Contrast the augmented exposure and possibilities from an anterior exposure (C). (A) and (B) redrawn by permission of Dr. Murray A. Falconer and the *British Journal of Surgery*, 35: 15, 1948.

postoperative ambulation is obtained and the period of hospitalization averages ten days; (8) the disability period is three to four weeks for sedentary workers and does not exceed three to four months for the heaviest occupations; (9) osseous union between the vertebral bodies is proved by (a) lack of vertebral displacement as seen in postoperative motion roentgenograms and (b) visualization of continuous osseous trabeculation in short focal spot magnification roentgenograms; and (10) the operation is applicable to and secures relief of symptoms due to degenerated intervertebral discs of the lower lumbar spine at any stage, regardless of previous operations having been performed posteriorly.

While these facts have been established by a previous publication [*11*], we wish to present some additional and, in some respects, more impressive data concerning (1) the application of the anterior excisional vertebral body grafting to patients with "recurrent" radicular pain and lumbago in which three or more operations have been performed from the rear, and to other types of complicated cases; (2) an evaluation of motion roentgenograms for aid in preoperative diagnosis and localization; (3) the use of volumetric criteria of disc injections with normal saline solution for precise selection of degenerated discs on the operating table; and (4) a presentation of long term end results.

While the objective of both the anterior and the posterior operation is the same, i.e., relief of symptoms of disc degeneration, the immediate aim of the anterior excisional vertebral body grafting operation differs from that of the conventional posterior excisional operation. The latter attempts only a removal of the particular fragment(s) thought to be offending, together with some additional portions of the disc. The resultant fragments which are removed can never equal those obtained under direct vision by an anterior approach. (Fig. 1.) Not only is the disc annulus removed more completely in the anterior operation, but stabilization (sacralization by fusion) of the contiguous vertebrae is secured.

In performing the anterior procedure, concern about the precise sector of disc, bulge or protrusion (marginal, central or subarticular) is unnecessary because of near-complete disc excision. There is little danger of damaging nerve roots, dura or intraspinal veins. There is no chance of perineural scarring, and vascular complications are avoided by visual control. The pathological condition of the disc is thoroughly appreciated, including visualization of posterior ligament bulges and protruding fragments. The fear of overlooking an intraspinal annulus fragment has proved to be groundless in an experience with nearly two hundred cases.

Points in Operative Technique. Space does not allow a detailed description of the operative procedure. This is found elsewhere [*10*]. Certain

TABLE 1

RESULTS FROM ANTERIOR DISC EXCISION AND VERTEBRAL BODY FUSIONS IN COMPLICATED CASES

Type of Case	No. of Patients	Relief of Symptoms		Osseous Union*	Return to Work	
		Radicular	Lumbago		No. of Patients	Average Time (mo.)
Multilevel disc degenerations at lumbar 3-4-5	3	3	2	2	2†	8
Multiple previous fragmentary disc excisions performed posteriorly‡ with transient or no relief	4	3	3	4	4	4
Gross anteroposterior spinal instability demonstrated on motion roentgenograms:						
A. Reverse spondylolisthesis or spondylolisthesis without pedicle defects	4	4	4	4§	3	4
B. Spondylolysis or spondylolisthesis with pedicle defects	6	6	4	4§	5	10

* Evaluated by the combined incidence of motion roentgenograms and short focal spot roentgenography.

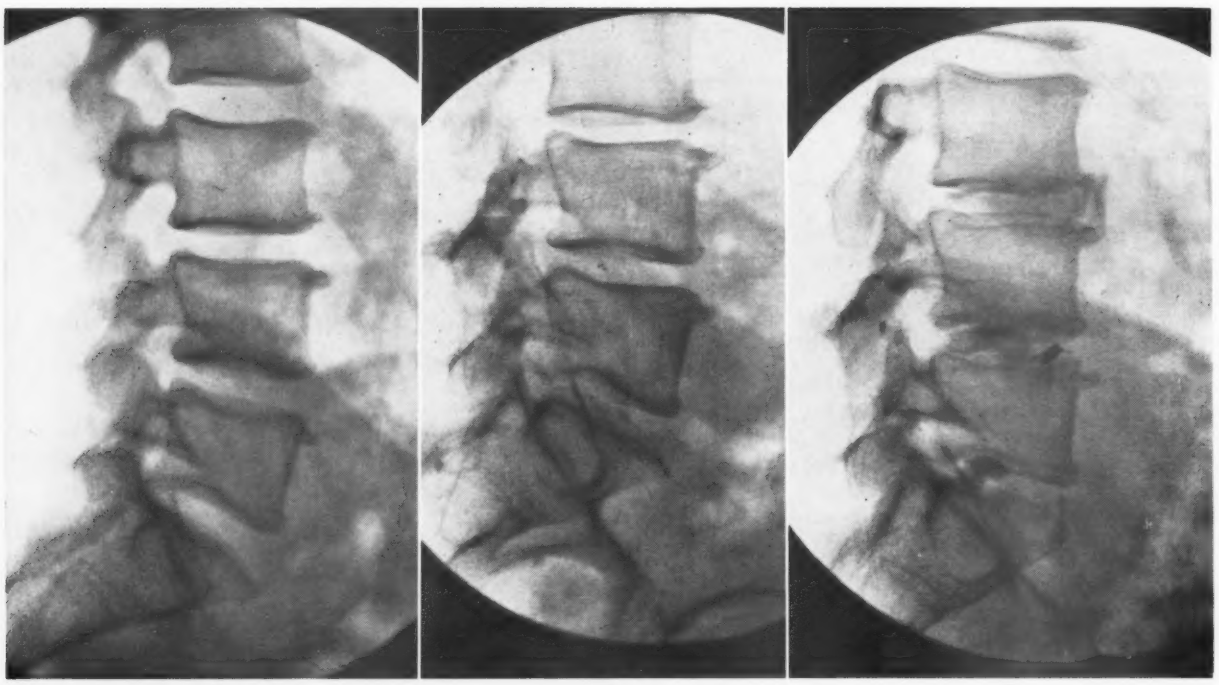
† Average time for undoubted union was six months, twice that of the average L-4-5 sacrum (two level) vertebral body fusion.

‡ To qualify for this category the patient must have had three or more fragmentary disc excisions from a posterior approach.

§ The patient who did not "return to work" was not a failure in this category, as he had worked very little during his adult life.

phases deserve review in explanation for the relatively short period of hospitalization and disability, freedom from postoperative complications and certainty of vertebral body union. Any surgeon who has performed lumbar sympathectomy has noted the ease of exposure of the lower lumbar vertebral bodies and their discs. The problems are: (1) a steady, adequate retractor exposure; (2) a knowledge of venous variations which are considerable and often formidable. Retractors which can be driven into the vertebral bodies for exposure of both sides of the field hold the peritoneum and left ureter to the right side of the field and the left iliac vessels to the left in the exposure of the fifth lumbar disc. The use of long instruments facilitates operation at such a depth. The selection of the precise discs (at least two or more in 83 per cent of cases) is made upon the basis of preoperative findings, routine and motion roentgenograms, myelography and discography (when these two latter have been performed). The final determining factor has been the external physical appearance of the disc and its volume capacity upon injection of a physiologic solution of normal saline or Ringer's solution. This will be explained in detail herein.

The interior of the disc is visualized after a flap of anterior ligament, the peripheral annulus, has been turned to the right. The usual thoroughly degenerated disc is removed piecemeal. Only discs in which the degeneration is central and/or posterior need curet dissection of the anterior and peripheral annulus from the cortical vertebral plates. Before the dissection of the disc contents proceeds far, the anterior vertebral lip and at least the anterior two-thirds of the cortical osseous plates are excised with an osteotome, permitting an amplified view of the posterior and lateral zones so necessary in removing the essential portions of the disc responsible for radicular symptoms. Posterior pockets are thus visualized and intraspinal fragments removed when present (15 per cent of cases). The forced impaction of supportive bone grafts of exact size interlayered with cancellous bone follows. Such a maneuver eliminates the postoperative symptoms of "spinal insufficiency" described in "disc fenestration" procedures [13] and seen in rapid loss of disc height in pyogenic space infections. Transverse



2A 2B 2C

FIG. 2A–C. X-ray films of some problems and results in a complicated and unstable case. Changes and findings over a seven-year period during which time the patient was treated with three sessions of recumbency traction in the hospital and underwent two fragmentary disc excisions from a posterior approach at lumbar 4 interspace. During this period the maximal relief from radicular pain was six months and there was no relief from low back pain except when resting. The patient has now had a year of full relief from both complaints following a three level (L-3 to L-5 spaces) anterior excisional operation and vertebral body fusion. A, 1951, lateral roentgenogram showing small osteophytes at L-3 and L-4 denoting advanced disc degeneration even then. B, 1958, preoperative view before anterior operation; osteophytes about the same size and there is some narrowing of the intervertebral spaces. C, 1958, postoperative view showing the grafts between the vertebral bodies.

placement of the grafts is important, as this is the best position to judge depth penetration.

The annulus anterior ligament flap is closed loosely with a mattress stitch of chromic catgut, controlling to some extent graft extrusion which has often been noted by our predecessors. The forced impaction of the grafts with the spine in extension likewise insures stability of the grafts.

Application of the Anterior Operation to Complicated and Recurrent Multilevel Intervertebral Disc Degenerations. While our total experience includes eighteen other "relapsing" and/or recurrent cases of low back and/or radicular pain (chiefly the latter) after one or two fragmentary disc excisions had been performed from a posterior approach, it is not considered that these are "complicated" cases for the purpose of this article. These cases have presented only routine problems and there has been sufficient disc material remaining at one or both lower lumbar levels so that the operation has not differed from a routine intervention in disc disorders operated upon for the first time. In operations performed posteriorly the apparent recurrence of radicular pain has usually been due to either a mistake in identifying the disc or an insufficient amount of degenerated disc annulus having been removed.

Our experience with true "complicated" cases is summarized in Table 1. These are either cases of demonstrated spinal instability with many levels of degenerative disc phenomena or cases of variable instability in which patients have undergone at least three or more operations posteriorly. A study of this table reveals a high percentage of satisfactory results in a small group of such cases in which there is usually extreme reluctance on the part of the surgeon to consider further surgical attack, or there is uncertainty as to precisely what to do. Myelograms in these cases are likely to be misleading or non-informative because the disc protrusion(s) is too far lateral to indent the dura or peridural; also, root scarring from previous operations will be further confusing. It

should also be pointed out that we were guided to a second, and in some instances to a third, disc level, either by direct demonstration of vertebral body instability or by the results of the saline injection test (see page 654).

The time of fusion of the vertebral bodies in these cases was noted to be prolonged to about twice that of uncomplicated cases, even though braces and casts and several weeks of recumbency were used in some grossly unstable cases. However, in spite of the prolonged time, an eventual good outcome was experienced (Fig. 2), except in a single patient with uncertain mobility.

Motion Roentgenograms and the Direct Assessment of Disc Degeneration by Injection of Saline Solution at Operation. Beginning with the early observations of Duncan and Hoen [*6*], Gianturco [*7*] and Knutsson [*15*] and continuing to the present, Hasner et al. [*12*], Begg [*5*], Allbrook [*4*] and Mensor et al. [*18*], a considerable body of data have accumulated that indicate that abnormal intervertebral discs, at least in the lower three lumbar sites, either diminish or abolish motion or are responsible for extraordinary anteroposterior instability. These data are recorded on roentgen films of the patient in flexion, extension and lateral bending, with the pelvis immobilized. Some of these observations reveal a lack of motion at vertebral discs above the level of grade 2 spondylolisthesis and other cases of anteroposterior sliding. Such findings point to clinical symptomatic degeneration of the disc at levels other than the spondylolisthesis or gross instability. It is necessary, therefore, to detect such abnormal discs by discograms or by injection of saline solution, and then dealing with them at surgery.

Most of the investigators on this phase of the disc problem agree upon a rather set pattern of lower lumbar spine mobility in the normal patient, although Tanz [*19*] is in disagreement. However, the latter author had no proof of disc normality in his subjects above thirty-five years of age. With strong evidence recorded that "clinically obvious disc disorders" (how detected, if often not stated), lead to an abnormal lumbar mobility pattern in all persons, we undertake to correlate preoperative observations on abnormal lumbar vertebral mobility with operative findings; the specific intervertebral discs are then selected for operative evacuation in most cases by the results of the saline injection tests under direct vision.

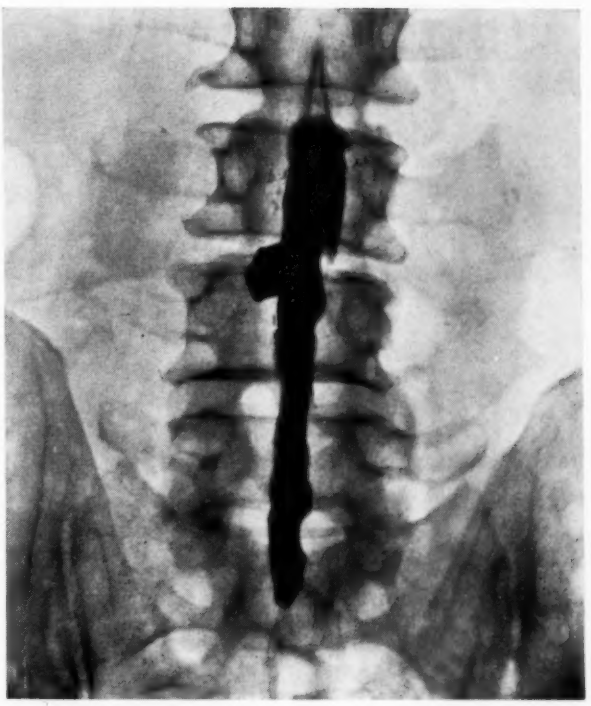
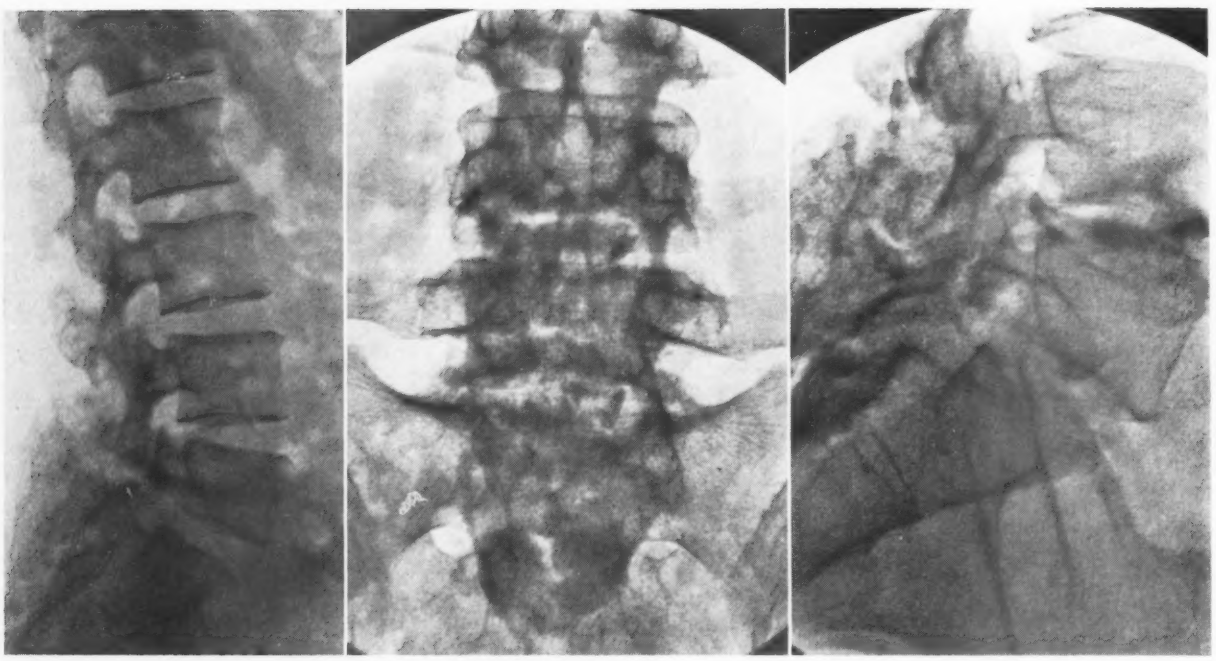


FIG. 2D. Preoperative myelogram (1958) showing deformed dural sac, probably due to peridural scarring. There is an atypical defect at L-5, the least degenerated of the three discs.

Our material for this study consisted of one hundred twenty-two sets of motion roentgenograms of persons suffering low back and variable radicular pain with and without recognizable or probable L-3-4-5 discogenic symptoms. These persons were successfully treated by conservative means and there were no operative data. Forty sets of motion roentgenograms were available of persons on whom anterior disc excisions and vertebral body fusions had been performed. Observations on the state of the discs and upon the amount of saline solution injected into each disc prior to excision were made in the latter group. Representative observations in this latter group are shown in Figure 3.

Persons with one or more severely or moderately degenerated lower lumbar discs regularly demonstrated one or more of the following phenomena, even when the disc height and appearance was normal in routine roentgenograms: (1) abnormal anteroposterior mobility (subject M. K.); and (2) suppression or absence of normal flexion-extension mobility at certain or all of the lower three lumbar interspaces (subjects F. K. and V. S.). An inspection of Figure 3 will demonstrate that there is no



3A 3B 3C

FIG. 3. Roentgenograms of 1955 and 1957 in a case of spondylolysis at L-5. There had been a previous misguided attempt to fuse three vertebral levels at two different operations from the posterior. A, 1955, lateral roentgenogram showing the L-5 defect with pseudoarthrosis at this level and absorption of the grafts at other levels. B, 1958, antero-posterior view one year after anterior fusion. C, 1958, lateral view showing amalgamation of the grafts. Has the pseudoarthrosis ossified?

absolute correlation between these findings and the level of disc degeneration when only one disc was involved (e.g., subject W. A., in whom even the clinically degenerated disc allowed normal motion). The same or analogous findings were observed in 20 per cent of the patients in whom conservative treatment sufficed for the time being. In the group operated upon, the incidence of the abnormal motion findings just mentioned was 90 per cent. There was no correlation of the level of suppression or diminution of motion with the injection findings, but the two together with the clinical findings in most of our patients constituted the indication for disc excision-fusion at a given level. The results of both immediate and long term treatment were highly satisfactory, and these observations are being continued. Abnormalities of the normal motion pattern of this region of the spine raise the index of suspicion of clinically significant degeneration of the disc, but a normal lumbar spine mobility pattern does not rule out the condition. A comparison to myelographic diagnostic accuracy will be presented herein.

Selection of the number and localization of the abnormal discs by the saline injection test has been a highly valuable procedure in anterior operations when the objective is removal of all symptomatic degenerated discs of the lower lumbar spine, and their replacement by bone grafts. The critical capacity is 1 cu. cm. at or below which the disc is considered normal. No normal discs have been encountered where the injected volume of saline solution is greater than this amount. Indeed, there appears to be an abrupt break of injectable volume: 1 or less cu. cm. (normal) to 2 or more cu. cm. (abnormal). When the disc is injectable with 4 or more cu. cm. there is obvious leakage into the spinal canal. Failure to inject less than 1 cu. cm. should be confirmed by four or more attempts at reinjection at slightly different levels and directions in the absence of radiographic control of the position of the needle tip. These volumetric criteria have been applied by us during the operation with the patient under general anesthesia, and the pain factor for localization commonly used in discography under local anesthesia has not been considered.

The number of discs excised on the basis of these findings is higher than that observed with the usual criteria employed in conventional

posterior excisions, and the immediate and long term results are correspondingly better. In ninety of our cases [11], the following distribution of degenerated discs operated upon was observed: lumbar, 5 only—seven cases (7.8 per cent); lumbar, 4 only—eight cases (8.9 per cent); lumbar, 4 and 5—seventy-two cases (80.0 per cent); and lumbar, 3, 4 and 5—three cases (3.3 per cent).

Nine- and Ten-Year Study of End Results in Thirty Cases. A small series of thirty-nine patients operated upon during the years 1948 and 1949 are still under observation. Nine patients have been lost to observation after a few years, but follow-up interviews, examinations, roentgenograms, including motion roentgenograms in all cases, and short focal spot magnification roentgenograms in some cases have recently been obtained in thirty cases. In evaluating these cases it should be pointed out that the amount of bone used for vertebral grafting was about half that now used, and forcible graft impaction and careful cortical plate excision was not practiced then.

Two cases were unsatisfactory from the onset, both patients having variable continuous lumbago, and one also having intermittent radicular pain. One patient was subsequently (six months) reoperated upon posteriorly by another surgeon, with apparent exacerbation of both lumbago and radicular pain over an eighteen month observation period. The operative findings were described by this surgeon as normal, with "little motion" at the interspace which had been grafted from the front. The case was terminated by a Workmen's Compensation settlement and the patient disappeared. The other patient received three separate small compensation awards for "recurrent low back sprain" over the ensuing four years, until another surgeon reoperated upon the previously unoperated fourth lumbar disc, posteriorly, and performed a posterior fusion with an almost complete alleviation of the patient's symptoms. This case is now interpreted as an error of omission caused by too much reliance on a single myelographic defect.

The remaining thirty-seven patients had relief from both low back and radicular pain. The latter pain usually disappeared when they awakened from the anesthetic; there was later disappearance of lumbago. Four patients exhibited symptoms of acute spinal instability for an average period of four weeks. In six months, thirty-one patients (83.5 per cent) were asymptomatic and at work, and in one year all had returned to their previous occupations. A significant number of dense fibrous unions (lack of displacement in motion roentgenograms but failure to demonstrate osseous trabeculation) were observed at this time, at one of every four spaces (Table II), but there were no symptoms and many later fused. It is certain that this early high incidence of slow osseous union was related to the operative technique in which the cortical osseous plates were not cut off.

TABLE II

FOLLOW-UP DATA ON THE EARLIEST AND LATEST CASE SERIES

Data	6 Months	1 Year	9 or More Years
1948–1949 Series (originally 39 cases):			
Symptom free	34/39	37/38	29/30
Union as seen in roentgenograms*	.....	26/30	27/30†
1957–1958 Series (90 cases):			
Symptom free	84/90	88/90	.....
Union as seen in roentgenograms	86/90	87/90‡	.....

NOTE: The denominator is the total number of patients followed up at a given time.

* Calculated on total number of vertebral spaces.

† 1948–49 Series 82.8 per cent (58/70).

‡ 1957–58 Series 98.6 per cent (164/167).

In the ensuing eight years, seven additional patients were lost to follow-up; one died of lymphoma five years later and the other six patients were lost to follow-up after more than four years. All seven had been fully relieved of low back and radicular pain and had no suggestion of recurrent discogenic symptoms. The remainder have since been followed up at intervals. Within the past year all thirty have been interviewed personally; examinations were performed and routine and motion roentgenograms were obtained. Short focal spot roentgen films have been taken in more than a third of the patients (see Figure 4 for two representative ten-year end results).

During the first postoperative year a third of the patients experienced various occasional minor low back pains and patchy radicular paresthesias. None of the thirty patients of the long term follow-up had any radicular pain or lumbago and they were unanimous in voicing the opinion that as time passed they had "forgotten about their back." There were,

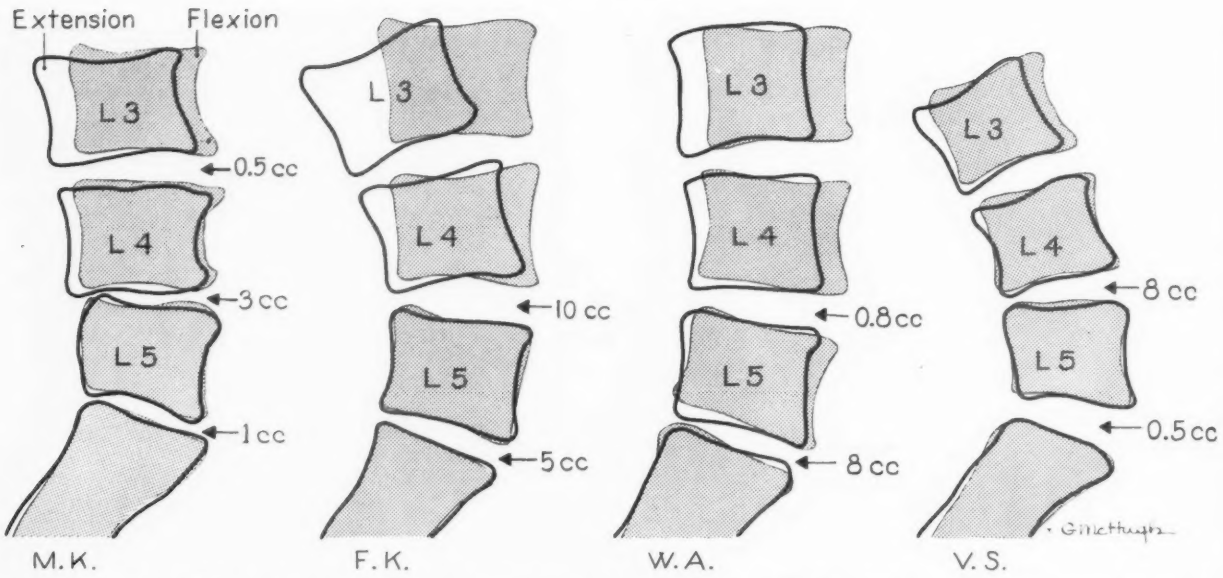


FIG. 4. Tracings of lateral roentgenograms in flexion and extension in four illustrative cases demonstrating representative alterations in normal lumbar spine motion in the presence of intervertebral disc degeneration. The volume capacity at injection under direct visual control at operation are shown. These together with the clinical findings are the guide to specific disc excision. Patient M. K., posterior sliding of L-4 on L-5 (spondylolithesis without pedicle defect) with the spine in extension. The defect disappears when the spine is in flexion. Patient F. K., minimal motion at L-5 with preservation of normal motion at L-4 in the presence of two severely degenerated discs. Both discs were excised and the interspaces fused. Clinically, this was a typical case in a young man of intractable radicular pain with missing Achilles jerk and sensory hyperesthesia in the L-5 dermatome. There was no alleviation of symptoms after three weeks bedrest prior to operation. Patient W. A., a similar clinical case to the preceeding one, but this case demonstrates that occasionally the abnormal disc (L-5) permits motion while there was none at L-4, the normal disc. Operation at L-5 only with full relief. Patient V. S., minimal motion and positive injection test at L-4, the space to which disc excision was confined. This patient also had full relief.

however, two notable exceptions; (1) a patient who had gained considerable weight and experienced occasional bouts of mild incomplete radicular pain, and (2) a patient who had fallen at home, and in whom a peculiar hemiplegic pain distribution subsequently developed without radicular findings on the contralateral side.

One-Year Follow-up in a Recent Series. The development of a more thorough and complete operative technique [*10*], some of the important points of which have been previously described, has resulted in fewer cases of postoperative lumbago and has virtually eliminated the troublesome muscle spasms of the "acute spinal instability syndrome." (Table II.) In the 1957 group of cases, only six patients (9.3 per cent) had any lumbago at six months, and

TABLE III

TIME REQUIRED TO RETURN TO WORK IN TWO SERIES OF CASES—ANTERIOR DISC EXCISION AND VERTEBRAL BODY FUSION

Series	No. of Cases	Percentages of Whole Group—Time (mo.)*					
		Less than 1	1 to 2	2 to 3	3 to 6	6 to 9	More than 9
1948–49 Series	39	5.1	7.9	30.8	38.4	10.2	7.6
1957–58 Series	90	2.2	25.5	32.2	27.7	10.0	2.2

* Impression was gained that some of the disabilities extending beyond four months were facilitated by disability insurance and litigation considerations in some cases.

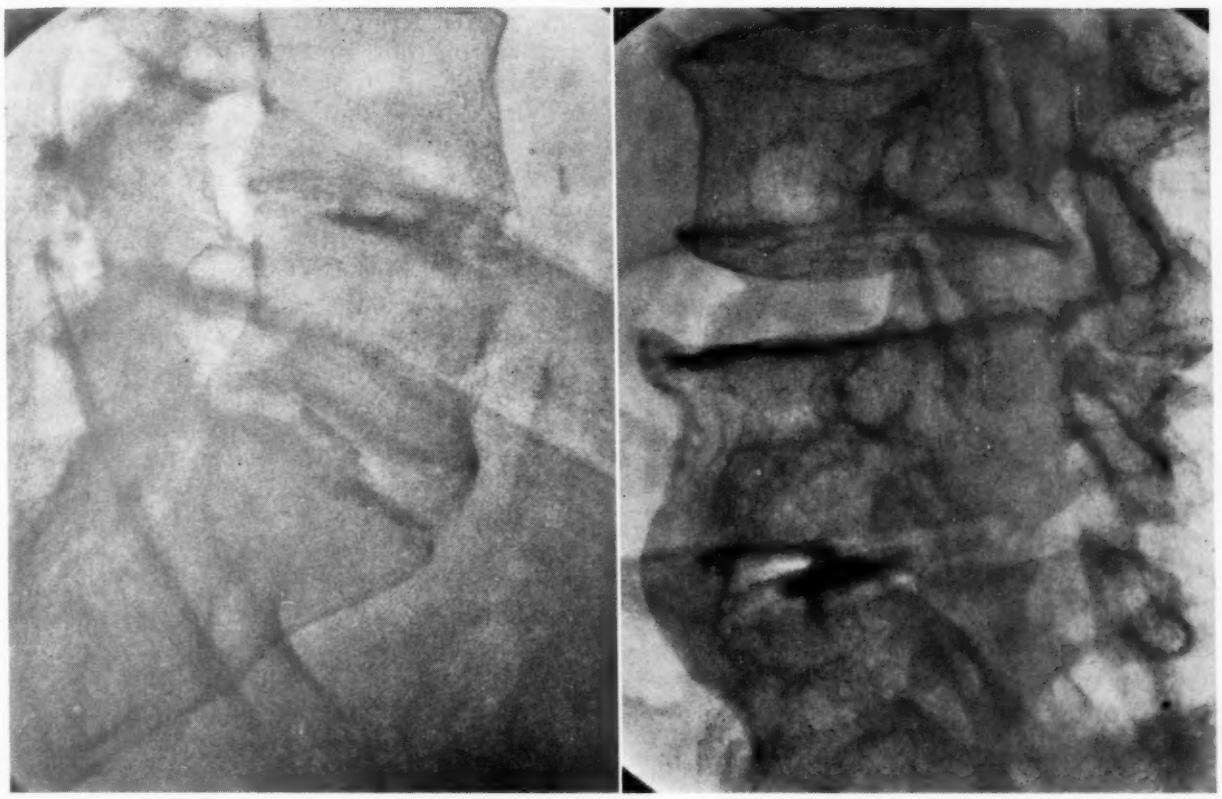


FIG. 5A and B. Lateral roentgenograms in two patients, demonstrating vertebral fusion at L-4 and L-5 ten years after operation. Both patients had excellent results and work daily at heavy occupations without back or radicular pain.

two (2.2 per cent) at one year with corresponding lack of movement in the motion roentgenograms (98.8 per cent fusions), calculated on the basis of individual interspaces. Moreover, bracing or casts have been employed in only a minor number of patients (15.6 per cent) and only on special indications, as unusual lumbago or slow union.

The same sequence was observed with this later group of patients as with the earliest series. The majority of patients were free of radicular pain on awakening from the anesthetic; others lost this symptom in a few days; a few lost radicular pain over a ten day to two week period and there was a transient contralateral paresthesia in a few cases. Low back pain was not as troublesome or as great in incidence, but a number of patients suffered dull low back pain when in bed or on excessive sitting or standing for several weeks. Few patients thought the degree of low back pain was other than annoying; it did not hinder their day-to-day activities during the convalescent period. Twenty-seven per cent were back at work, chiefly sedentary occupations, at the end of two months as compared with 13 per cent in the former series. (Table III.) In three months, 59 per cent were working as compared to 44 per cent.

COMMENTS

It is my opinion that the current unsolved problems in the surgical treatment of discogenic disease of the lower lumbar spine are three: (1) relapsing and recurrent radicular pain; (2) the treatment of "postoperative" lumbago, which in some instances is due to spinal instability and in others to other symptomatic discs in the area that may or may not have been subject to surgical attention; and (3) a more exact and comprehensive preoperative test(s) to indicate whether or not more than one disc is responsible for the symptons and to indicate the total number and identity of the offending discs.

The problem of relapsing and recurrent radicular pain, seen in a certain percentage of all patients operated upon by the posterior

fragmentary exisional technique, is solved by the anterior subtotal excisional operation followed by vertebral body fusion when all the symptomatic and degenerated discs have received attention. In our total experience with nearly 200 cases, the few instances of recurrent radicular pain have been errors of omitting operation on a second symptomatic disc at an early stage in the evolution of this operation when too much reliance was placed upon spinal myelography. Even the ten-year follow-up in our earliest series of patients who were operated upon by a technique which we believe at this time to have been somewhat inadequate demonstrates that 93 per cent of these patients who have returned to work have been oblivious of their back and former radicular difficulties. The patients in this category are enthusiastic about the result over this period.

Since our latest series demonstrates 98 per cent fusion of the vertebral spaces operated upon, the problem of spinal instability and long term "postoperative" lumbago has likewise become minimal. The fourth lumbar space is apparently fused with slightly greater difficulty than the lumbosacral space in which there have been no failures in either series. It is our present routine to subject the patients to motion roentgenography four months postoperatively, and to brace those patients who have significant motion at the fourth lumbar space. Those who have had lumbago lasting more than eight weeks have already been braced. It should be pointed out that motion roentgenograms taken at four months, when there is as yet no significant osseous union, often show no motion at the operated levels. Thus, the indication of continuing or increasing lumbago appears to be a safer criterion for spinal bracing. Braces are unnecessary in most cases, except in those patients in whom abnormal anteroposterior sliding is seen in the preoperative roentgen films. Reference to Table 1 indicates a 75 per cent salvage rate in a small number of patients who have each undergone more than three fragmentary disc excisional operations from a posterior approach. The percentage of successful vertebral body fusions in patients with gross vertebral instability also indicates that the anterior operation achieves relief of both radicular pain and lumbago in these difficult cases as well as in the routine surgical cases of radicular pain due to discogenic disease of the lower lumbar spine.

It is well recognized that myelography has an upper diagnostic limitation of approximately 70 per cent. The reasons for the diagnostic limitation of myelography are well understood and need not be repeated here. A few myelographic defects are old lesions and the symptomatic disc may be the adjacent one. Discography, when performed with technical accuracy, will indicate multiple disc degenerations. Our injections into discs under visual control at operation probably has the same significance. The operative injection has the satisfaction and ease of visual control and moreover eliminates a formal preoperative discogram. The combined employment of preoperative motion roentgenograms and injections of saline solution into the disc has been highly indicative of the extent and number of discs that are degenerated. It should be pointed out that there is nothing specific about the lack of preoperative motion in roentgenograms and more over this method is subject to other pitfalls, so that we use motion roentgenograms as an auxiliary general guide. We are likely to continue on a non-operative program for a more prolonged time when there is normal motion at the three lower lumbar spaces, obviously also evaluated on the patient response. It is my opinion that the combined employment of preoperative motion roentgenograms and injection of saline solution into the disc under visual control eliminates the need for myelography for any purpose except differential diagnosis.

CONCLUSIONS

1. An improved technique for anterior subtotal extraperitoneal intervertebral disc excision and vertebral body fusion has resulted in symptomatic relief in the patients with ninety-eight per cent fusion, calculated on the basis of the total spaces operated upon. There are few recurrences of either radicular pain or lumbago. Some statistics are presented of ten-year end results.

2. The operation is also of value as a salvage procedure in patients who still have symptoms after having undergone one or many fragmentary disc excisional operations from a posterior approach. Vertebral body fusion in all cases and 75 per cent relief from all symptoms is reported in four remarkable cases in which the patients had undergone three or more frag-

mentary disc excisional operations prior to the anterior operation.

3. The anterior extraperitoneal operation as now performed, including forcible impaction of grafts into the intervertebral space after it has been cleared of cartilage and of considerable cortical bone of the vertebrae, is one which produces no shock and is well tolerated by the patient. No blood transfusions and little spinal bracing is needed. The patient rises on the day following operation. The median period of hospitalization is ten days, and by three months 60 per cent of patients are back at work (most occupations).

4. The evidence of vertebral body union is (1) freedom from all types of radicular and lumbago symptoms; (2) no displacement in postoperative motion roentgenograms taken more than six months after operation; and (3) the osseous trabeculation continuous between vertebral bodies and grafts in the clarity of roentgenograms made by the short focal spot magnification technique.

5. Some data are presented on the utility of preoperative motion roentgenograms as a scout filming program in the diagnosis and selection of cases for operation.

6. The injection of saline into the intervertebral disc for the diagnosis of disc degeneration under visual control at operation is described.

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Early Management of the Fractured Hip

JAMES G. STEPHENS, M.D. AND WORTHINGTON G. SCHENK, JR., M.D., *Buffalo, New York*

From the Department of Surgery, University of Buffalo School of Medicine, and the Edward J. Meyer Memorial Hospital, Buffalo, New York.

THE early management of the fractured hip was instituted in the general surgical service of the Edward J. Meyer Memorial Hospital, Buffalo, New York, in January 1956, to determine whether early treatment of the fractured hip would yield better results than delayed treatment. On alternate months patients with fractured hips were treated by the orthopedic service which continued to treat the fractures as elective procedures, and these cases comprised our control group. The early management of the fracture does not mean emergency operation immediately after admission; it does mean within a twenty-four hour period, during the daily operative schedule, which sometimes requires postponement of previously scheduled surgical cases. The patients in both series were treated by the resident staff, along with consultation and supervision by the general surgical and orthopedic attending staffs. These series include all patients with fractured hips admitted to the E. J. Meyer Memorial Hospital, which is a large county hospital. The mortality figures are hospital mortality figures, whether or not the cause of death is related to the fractures.

We also separated the cases of fractured hips into two groups: (1) Those in which the patient was ambulatory, and (2) those in which the patient was bedridden because of chronic illness.

A previous report from this hospital by Schenk [1] on two series of 120 cases was also used as a comparison. Table I shows the significant decrease in mortality of the present series of patients who were treated as semiemergencies.

Our mortality rate of 18 per cent in the present series shows a statistically significant drop when compared to the control group, in which there was a mortality of 38 per cent. The reason for the fall in the mortality rate may be due to the marked decrease in the average time from admission to operation as shown in Table II.

The average time from admission to the internal fixation in the present series was 2 days as compared to 5.4 days in previous series and 4.2 days in the control group. Sixty-two per cent of the patients were operated upon within twenty-four hours. Surgery was deferred in fourteen patients for more than forty-eight hours because of severe complicating illnesses. The present series also showed a further increase in the number of patients undergoing internal fixation, without increasing the surgical mortality. (Table III.)

These figures seem to support the claim that early operation does decrease surgical mortality as well as over-all hospital mortality. The fractured hip remains a serious problem

TABLE I
MORTALITY RATES

Series	No. of Cases	Mortality (%)
1946–1948	120	36.7
1953–1954	119	27.8
1956–1958 (control group)	76	38.0
1956–1958	94	18.0

TABLE II
INTERVAL FROM ADMISSION TO SURGERY

Series	No. of Days
1946–1954	5.4
1956–1958 (control group)	4.2
1956–1958 (early surgery)	2.0

TABLE III
PERCENTAGE OF PATIENTS OPERATED UPON AND SURGICAL MORTALITY

Series	Total Operated upon (%)	Surgical Mortality
Series A 1946–1948	56.5	26.5
Series B 1953–1954	80.0	25.6
Control group 1956–1958	86.8	28.6
Early fixation 1956–1958	96.7	16.6

TABLE IV
AVERAGE AGE

Series	Survivors (yr.)	Deaths (yr.)
Series A 1946–1948	72	79
Series B 1953–1954	73	78
Control group 1956–1958	72	81
Early operation 1956–1958	80	86

TABLE V
PHYSICAL STATUS BEFORE SURGERY

Group	No. of Patients	Deaths
Ambulatory	73	6 (8%)
Bedridden	21	11 (52%)

in the older age group and there is a significant age difference between survivors and those who died. This is shown in Table IV.

The semiemergency treatment has apparently increased the average age of the survivors while those who did not survive were far advanced in years.

In an attempt to determine how many of these patients were in the process of a severe illness with fracture of the hip as the terminating incident, we divided the patients into ambulatory and bedridden groups. These are shown in Table V, along with their respective mortality.

These figures would suggest that mortality is increased in the bedridden person who cannot be made ambulatory after stabilization of the fracture. These patients are also chronically ill, debilitated and frequently residing in nursing institutions.

TABLE VI
NO. OF DAYS FROM INJURY TO ADMISSION

Series	All Patients (days)	Survivors (days)	Deaths (days)
Series A and B	2.7	...	...
Control series	2.2	1.6	2.8
Early operation	2.2	1.8	2.5

TABLE VII
TOTAL HOSPITAL DAYS

Series	No. of Days
Series A	62
Series B	47
Control series	47
Early operation	27

Another reason for early operation, rather than treating these cases as emergencies immediately upon arrival, is that many complications have already developed between the time of injury and admission. This interval has been shortened from our previous series, but there remains a considerable delay as shown in Table VI.

Thus there is a need for earlier diagnosis and referral to the hospital, as well as early operation upon arrival. Many of these patients in whom cardiac and pulmonary complications have already developed require more than twenty-four hours preparation prior to surgery.

Early operative management also had a pronounced effect on total hospital days as illustrated in Table VII.

A more vigorous approach has not only reduced hospital mortality but shortened hospital stay and greatly reduced the cost of hospitalization.

In both our present series, there were slightly more females than males admitted with fracture of the hips. All types of hip fractures were included and the distribution is shown in Table VIII.

The mortality was approximately the same in patients with intracapsular fractures as in those with extracapsular fractures.

Spinal anesthesia may be of benefit in these elderly patients, as shown in Table IX.

The marked increase in the mortality of

TABLE VIII
TYPES OF FRACTURES

Series	Subcapital	Intertrochanteric	Subtrochanteric
Early surgery	44	41	9
Control group	42	29	5

TABLE IX
TYPE OF ANESTHESIA USED

Series	General	Spinal	Local
Control			
Survivors	24	21	0
Deaths	10	9	0
Early operation			
Survivors	16	52	4
Deaths	8	6	0

patients receiving general anesthesia would lead one to believe that the increased use of spinal anesthesia is beneficial in altering the mortality rate.

SUMMARY AND CONCLUSIONS

1. Early treatment of the fractured hip does yield better results than delayed treatment. The semiemergency treatment reduced mortality 50 per cent as compared to the control group.

2. Bedridden patients who are dying and have a fractured hip have a much higher mortality than those patients who are seriously ill because of an accidental fracture.

3. The trend toward early internal fixation in practically all cases has decreased the mortality.

4. Mortality figures suggest that spinal anesthesia is safer than general anesthesia in the patient with fracture of the hip.

5. The lag period from the time of injury to admission has not changed significantly. This requires an awareness of the diagnosis and early referral to the hospital for x-ray examination and admission.

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Emergency Room Experience in a Community Hospital

EARL B. SANBORN, M.D., *Evanston, Illinois*

THE hospital in a community of a metropolitan area, or a smaller city, offers a number of services. One of the most important service is that provided by the emergency room. A patient who has sustained severe trauma may continue to live as a result of the treatment initiated or continued there.

A recent publication has given the facts concerning the number of general hospitals with emergency rooms, as well as the number of general hospitals (with their bed capacities) in America [*1*]. These data are given in Table 1. Apparently, there are over 5,000 general (community type) hospitals with a bed capacity under 300 in America, and 85 per cent to 90 per cent have emergency rooms. One can easily conclude that a physician should receive instruction in the treatment of trauma in medical school before he has assignments as an externe, interne, resident, or attending surgeon to the emergency rooms in hospitals.

What subjects should be included in medical school courses concerning trauma that will provide a basis for future responsibilities in participating in the management of patients sustaining trauma? In order to answer this question, I thought it would be feasible to review the cases to which responsibility was assigned at a community hospital during a three-year period. This period followed a thirteen-year interval after internship in which

TABLE 1
DATA ON GENERAL HOSPITALS

No. of General Hospitals	Emergency Rooms Available (%)	Bed Capacity
Federal (319)	87.4	.....
Non-federal:		
Long term (92)	27.1	.....
Short term (4,606)	86.8	.....
768	....	Under 25
1,420	....	25–49
1,308	....	50–99
1,018	....	100–199
492	....	200–299
360	....	300–499
180	....	500 or over

TABLE II
WOUNDS SEEN IN THE EMERGENCY ROOM

Wounds	No.		No. of Patients Admitted
Lacerations (one or more):			
No sutures or bridges	98		..
Adhesive bridges used	22		..
Sutures used	363		6
		483	
Contusions (one or more):			
Roentgenograms taken	167		2
Roentgenograms not taken	66		1
Complications of contusions	16		..
		249	
Abrasions (one or more):			
Roentgenograms taken	13		..
Roentgenograms not taken	25		..
		38	
Contusions and abrasions:			
Roentgenograms taken	25		3
Roentgenograms not taken	10		..
		35	
Partial amputation of fingers	6		1
Burns:			
First and second degree	42		..
Second and third degree	2		2
		44	
Puncture wounds:			
Uncomplicated	34		..
Complicated	5		..
		39	
Avulsion wounds	13		..
		13	
Total		907	15

TABLE III
WOUNDS SEEN IN THE EMERGENCY ROOM

Wounds	No.	No. of Patients Admitted
Fractures:		
Closed	118	22
Open	2	..
Fractures and dislocations:		
Same patient	2	..
Dislocations	14	1
Whiplash injuries	17	1
Injuries to the knee:		
Other than sprains	3	1
Acute injuries to lower back	3	2
Strains	5	..
Eye:		
Complications of foreign bodies	8	..
Bites:		
Dogs and cats	18	..
Human and insect	3	1
Sprains:		
Roentgenograms taken	76	1
Roentgenograms not taken	8	..
Foreign bodies:		
Eye, ear, nose and throat		
Removed	13	..
Not found	4	..
Other areas		
Removed	35	..
Not found	2	..
In food passages	30	15
Total	361	45

TABLE IV
MULTIPLE INJURIES AND OTHER CASES

Injuries	No.		No. of Patients Admitted	
Multiple injuries:				
Injuries to the head	23		17	
Fractures	35		17	
Fractures, and injuries to the head	9		9	
Other type (tendon, etc.)	51		18	
		118		61
Injuries to the head	8		4	
		8		4
Miscellaneous:				
Bursitis after trauma	3		..	
Loose teeth	1		..	
"Tension on sciatic nerve"	1		..	
Bleeding	1		1	
		6		1
From skin lesions (trauma)	2		..	
From non-trauma (?)	5		..	
From dental extractions	2		1	
		9		1
Total		141		67
Total of Tables II and III		1,268		60
Grand total		1,409		127

residencies and full time hospital appointments had resulted in certification by the American Board of Surgery and Board of Thoracic Surgery. These previous appointments with experiences on services of the surgical specialties had stimulated an interest in trauma. As attending surgeon on call in the emergency room (for twenty-four–hour periods, several times a month) and as a consultant, over 1,400 patients were either personally seen or management of their cases was discussed with a member of the house staff over the telephone. (Tables II through IV.)

WOUNDS

The management of wounds consumes the surgeon's attention, especially the one who deals with trauma. Approximately 65 per cent of the cases in this series were of injuries of the soft tissues. A number of the lacerations did not require suturing, but the majority did. It was not a routine policy to uniformly take roentgenograms of all cases of contusions, abrasions, or other types of trauma to the soft tissues. However, roentgenograms were taken of approximately 75 per cent of the contusions, abrasions and sprains. Certainly a more accurate diagnosis is possible with their use.

The complications of untreated contusions were mainly infections, and were the reasons for the patient presenting himself at the emergency room. These complications included paronychias, abscesses, cellulitis, tenosynovitis and lymphangitis. Subungual hematomas, hematomas (infected and non-infected) and bleeding from varicose veins, and avulsion of nails were other complications.

It was necessary, or considered good judgment, to hospitalize only two of the patients with burns. These patients were less than two years of age and sustained burns less extensive than 30 per cent of the body surface. There were no serious complications from ambulatory treatment in the other patients with burns.

There were five cases of puncture wound

with complications. These consisted of cellulitis, paronychia and lymphangitis.

MUSCULOSKELETAL INJURIES

Approximately 18 per cent of patients in this trauma series sustained injuries to the musculoskeletal system, and this calculation does not include those in the group of cases with multiple injury, where 50 per cent of the patients had effects of trauma involving these systems of the body. It can easily be concluded that the responsibility of the care of these patients cannot be left entirely to the orthopedic surgeons. The decision as to which surgical service, or specialist, takes care of the patient frequently depends upon whether or not the osseous system is involved. In some teaching hospitals, such involvement means treatment only by orthopedic surgeons. However, in a community hospital, this unwritten rule may not exist. For this reason, the responsible attending surgeon on call should know the management of most fractures, or musculoskeletal injuries.

INJURIES TO THE HEAD

In this series there were only cases of closed injuries to the head. Most of the patients were hospitalized, but several patients with cerebral concussion were permitted to go home with the understanding that the patients were to be closely observed. In addition, the responsible relative was carefully instructed to bring the patient to the emergency room immediately if any significant sign or symptom became apparent.

MULTIPLE INJURIES

A patient with multiple injuries may be defined as a patient who has sustained trauma to more than one of the systems of the body. For this reason, the cases in which tendons were divided were considered cases of multiple injury. The seriousness of injuries to the head and chest in cases of multiple injury has been described in a previous publication [2].

THORACIC INJURIES

A relatively small number of patients with multiple injuries had injuries involving the thorax and its contents. Most of these involved fractures of the ribs. One patient with a pneumohemothorax, due to a gunshot wound, required the insertion of intercostal tubes (connected to water seal drainage) before the abdomen could be properly explored (because of another penetrating wound).

MORTALITY RATE

In this series, there was one death. The patient was admitted to the hospital after an emergency tracheostomy was performed in the emergency room, and died shortly thereafter. The coroner's physician did not authorize, or perform, an autopsy, but concluded that the patient had a fracture of the cervical spine with an associated injury to the spinal cord in addition to fatal craniocerebral injuries. Another patient with multiple injuries arrived in the emergency room without an obtainable blood pressure or radial pulse. Cooperation and efficient teamwork resulted in the successful treatment of this patient, who was discharged from the hospital six weeks after admission, in relatively good health for his age. He is now a healthy senior citizen.

HOSPITALIZATION

Some hospitals do not like to have an emergency service because a certain number of beds are required to properly care for injured patients requiring hospitalization. Less than 10 per cent of this series of patients were hospitalized.

TEACHING PROGRAM

This study has revealed that instruction in trauma should be given in the medical schools relatively early in the four-year course. If the non-professional public is to be trained for possible eventualities, certainly the medical student should be instructed likewise. Some medical students serve as externes before graduation. They would benefit by such early instruction also.

Two of the publications of the American College of Surgeons [3,4] on trauma could certainly be used as a basis for the teaching of trauma in medical schools and during internship. Additional reference books, including monographs on injuries to the hand, fractures, injuries to the head, etc. would be helpful. One subject which is not taught in some medical schools to any degree is the management of foreign bodies, especially those in the food passages. Usually a consultant must be called in for these cases. The subjects listed in Tables

II through IV should be included in a teaching program.

SUMMARY

Data on three years' experience with patients admitted to the emergency room of a community hospital is presented. Attention should be given to the types of trauma in these patients by those planning teaching programs for instruction in trauma in medical schools and internships. The need for this instruction is emphasized by this report.

Acknowledgment: Grateful appreciation is accorded to Dr. O. T. Roberg, who first assigned me to the emergency room on call list at the Swedish Covenant Hospital, Chicago, Illinois, and to Dr. Michael Mason, who kindly sponsored this presentation.

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The Mechanisms Involved in Skiing Injuries

L. Allan Erskine, M.D., *Palmerton, Pennsylvania*

This paper is presented in an attempt to widen the understanding among doctors, particularly non-skiing ones, of the how and why of skiing and the resulting injuries. In the past ten years there has been a marked increase in the number of skiers, and a corresponding increase in the injured although, fortunately, the injury rate has dropped considerably. Recent reviews have shown it to be 2.7 per 1,000 skiers per day. During the 1956 to 57 season it was estimated that there must have been at least 110,000 injuries directly resulting from the sport. In view of this, I would like to go over briefly the basic techniques and equipment used by skiers, and the part they play in the complex and often serious injuries which occur.

The only knowledge that many people have of the sport is what is presented by newsreels, television and public press. It is a common misconception that skiing consists of a person soaring through the air with two boards on his feet and landing on them, if lucky, in the snow below. Ski jumping, of course, is a highly specialized sport in itself and bears the same relationship to skiing as high diving does to swimming; only about 2 per cent of all skiers jump.

There are other variations of the sport. In the United States today downhill skiing is the most popular. The participant is taken to the top of a hill, by one means or another, and then comes down on his skis via a trail or open slope. In the course of the descent he has to make turns, dodge obstacles, and be able to stop or control his speed. The inability to execute any of these is the cause of most downhill accidents.

A less popular, but probably safer, variety is touring or cross-country skiing. This is very popular in Europe, but has few devotees in North America where the idea of walking uphill is not attractive.

Twenty years ago ski-joring was popular, but has almost died out today. This amounts to being towed, usually by a horse, occasionally by car or plane, along a road or open field. Its counterpart today, of course, is water skiing.

The injuries discussed here are limited to those injuries which result from downhill skiing. Many people are injured on tows, lifts, etc., and many more are hurt as spectators. These I will not discuss.

Before going into the actual mechanics of these injuries, the equipment should be understood. In skiing, one attaches the body, via the lower extremities, to two platforms of wood, plastic or metal, varying in length from 5 to 7½ feet and about 3 inches in width. These skis have small grooves about ¼ inch deep and ⅜ of an inch wide running down their undersurface which acts as a type of negative keel. They keep the skis running in a straight line. Each side of the bottom or sole is clad with a steel edge which is quite sharp, and which, at an inopportune moment, can inflict a severe laceration. The skis are attached to the boots by a variety of harnesses or bindings, all designed to bind the boot to the ski with as little play as possible. Some bindings are designed to release whenever there is an abnormal torque applied, and are usually adjustable. Some newer types also automatically release the heel when there is a sudden forward thrust. These are known erroneously as "safety bindings," and more correctly as "release bindings." A short leather thong known as a "runaway" or "safety" strap is clipped between the boot and the binding to prevent the ski from running free down the slope should it come off. (Each year several injuries are reported resulting from skiers being hit by loose skis.)

The conventional bindings consist of a heavily sprung metal cable which has a tightening device on it. This passes around the shallow groove in the heel of the boot, and

when the tension is applied the toe of the boot is forced into a steel toe piece, locking it onto the ski. Some vertical play is allowed in the heel.

The ski boot is probably the most critical item of equipment, and its proper fitting is vital to the skier. The demands made on it are many, and as a result its design has undergone many changes. The boot is the connection between the foot and the ski, and is the means by which the skier controls the ski; it must fit snuggly enough so that every motion of the foot and ankle is transmitted to the ski; it must not be so tight as to impair circulation; it must be reasonably waterproof and have some insulating properties to guard against frostbite; it must be rugged enough to withstand the vise-like grip of the binding. Most of the boots today have tried to achieve tightening without interfering with circulation by using some type of built-in ankle corset with a separate lacing; some use inflatable cuffs, similar in principal to the sphygmomanometer cuff, which are inflated after the boot is on, etc. It has been my own experience that, while cold feet are common, actual frostbite of the toes in active skiers is, fortunately, not often seen. The boots are usually worn over two or three pairs of socks, an underpair of cotton or nylon to absorb moisture, and then one or two thick woolen pairs. These are necessary for warmth although they do allow a certain undesirable amount of play between the boot nnd the foot.

The last item of equipment which should be mentioned is the poles. These are used for walking and climbing, and also are a great factor in balancing while traveling at speed. All have a sharp point and a "basket" or snow ring to keep them from sinking in the snow. They are responsible for a number of injuries each year since they can break off or one can be speared by the points. The skier can also trip over his own poles with disastrous results.

Having briefly reviewed the equipment involved, I shall next discuss the ballistics of normal skiing. The term ballistics is used deliberately since a skier traveling downhill at thirty miles per hour behaves like, and has many of the characteristics of, a missile.

Let us look at a skier going straight down a slope. Assuming that he is an expert, he will have his skis quite close together, maybe a distance of three or four inches apart. His body is leaning slightly forward; the knees are bent a little in order to act as a shock absorber should he hit a bump; the weight is kept over the skis; the poles are held away from the body and kept well back. In this position he has excellent fore and aft stability, and also, if he is moving at speed, he will have considerable lateral stability helped to a certain extent by the poles.

Running free down a hill great speeds can be reached. In racing, sixty miles per hour is not uncommon. However, the average skier does not do more than forty-five miles per hour in his recreational skiing, and then only occasionally under excellent snow conditions.

A normally built person weighing 150 pounds, and moving at a fairly constant speed of thirty miles per hour, develops a momentum of 6,600 foot-pounds per second. This means that he has enough energy to raise a 6,600 pound weight 9 inches in the air. According to formulas developed in the study of automobile crashes, if he stops in a distance of 2 feet the stopping force applied would be 2,250 pounds or 15G; if the stopping distance is shorter, this figure goes up astronomically. (Fig. 1.) If something goes wrong, and the force is exerted in such a way that the skis act as levers, a moment is created, and the force is increased several times.

Speed is controlled by several maneuvers, each of which depends in turn on the type of snow and the speed. The usual form of checking speed is to make a series of short turns. The abruptness of the turn and the length of the connecting run across the slope (or traverse) determines the degree of slowing. In order to utilize this type of checking, a fairly broad slope is required.

On a narrow trail it is necessary to brake by "snow plowing." Here the knees are brought together and the feet externally rotated, pushing the heels of the skis apart and bringing the tips together; meanwhile the entire ski is edged against the snow, literally forming a snow plow. It is a fine method for stopping when moving at slow speeds; however, at high speeds it requires much effort to hold this snow plow position for any length of time, as most of the force is taken up by the internal collateral ligaments of both knees, and the adductor muscles. It is a relatively easy position and is about the first thing learned by most beginners.

The most efficient means of checking speed is one of a series of turns all based on side-

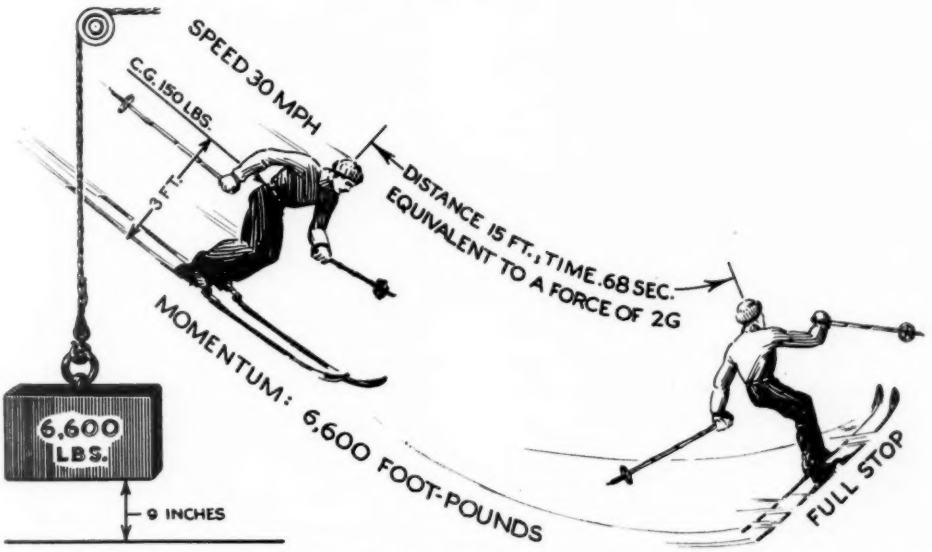

FIG. 1. Showing the various forces involved in a normal stopping turn or "Christy into the hill."

slipping the skis, that is, keeping the sole of the ski flat on the snow, and allowing the acquired momentum of the skier to swing them around helped by the proper changing of the weight. When carried out with the skis in the snow plow position, it is called "stemming"; if the skis are together and parallel, it is a Christiania turn or "Christy." Stem turns can be made at slow speeds, but the Christy is a "dynamic" turn which requires a certain amount of speed before it can be executed.

Two other factors which play a large part in the accident rate should be mentioned. One is fatigue. It is a well substantiated fact that about 50 per cent of all skiing injuries occur after 2:00 P.M. when people are starting to tire. One area has even reported that this rate is much higher after 2:00 P.M. on Sunday than on Saturday, when people are preparing to leave after a strenuous week end. Fatigue, of course, interferes with control, and lack of control leads to an accident. The second factor is fear, a purely psychological one, and about which we have little objective data. A skier who is relaxed and happy rarely gets hurt. When frightened, he becomes tense, the legs lose their suppleness and the reaction time slows up—a good set-up for an accident. The cause of the fright is usually a situation which the skier is not trained to handle: the slope may be steeper than expected, getting up too much speed, etc.

Now let us see just what happens when an accident occurs and why. Two basic types of mechanisms are involved in all downhill accidents, except for the direct collision with a fixed object or another skier.

The first type of accident is the one which occurs from a straight downhill position. (Fig. 2.) For some reason or other, usually crossed skis, striking a small obstruction, or running into soft snow from hard packed snow, the forward motion is abruptly slowed or stopped. The skier lunges forward in the direction of this motion propelled by his own momentum which is 6,600 foot-pounds per second. His feet are fixed on the skis by his boots and bindings. If he has release bindings, the skis will come off, he will catapult forward and land in a snow bank with little injury

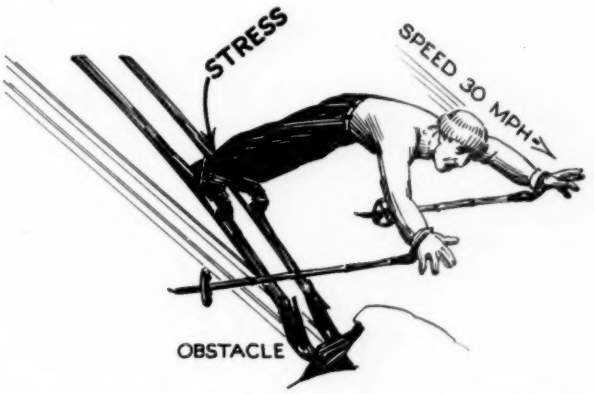

FIG. 2. Hypothetical illustration of an instantaneous full stop while running straight downhill.

FIG. 3. The beginning of a fall while turning. Note the buried outer edge of the downhill ski, and the rotation of the other leg and body on the fixed leg. Momentum will tend to make skier fall in direction of original motion.

except to his ego. If the bindings do not let go, it is a different matter. The forward motion carries the person in an arc. If the tips of the skis are fixed, the full thrust of the momentum is transmitted through the legs to the ankles, and something has to give. It may be the tendo-achillis or the peroneal groove, and/or the skis. This actually can happen occasionally when standing still: the skier leans forward to test his bindings, and literally "hangs" in them; the peroneal tendon may slip out of the retinaculum or it may actually tear off.

Actually, when a forward fall happens and the tips of the skis are free, the person goes into what is commonly known as an "egg beater" spin, rolling forward with ski poles and skis flailing in all directions for distances up to 50 or 100 feet. When this happens, the momentum is dissipated over a considerable period of time and distance, and hence is not as damaging as when the stop is instant. The injury most often seen in this fall is a dislocated humerus, and, less frequently, a spiral fracture of the leg bones. The fracture results from the victim rolling over with his skis crossed. This causes quite a forceful torque on one or both tibia (as much as a 600-pound twist). Also, lacerations of the leg can occur from the sharp ski edges.

Accidents which occur while turning are the ones which are of interest from the anatomical as well as the physical standpoint. Here we have a rotational motion with resulting torque entering the already complex pattern of forces. (Fig. 3.) In turning, if the tips of the skis do not skid around and are fixed, they act as a fulcrum and two moments come into play to amplify the forces already developed by the skier. One of these is the moment between the tip of the ski and the ankle (a distance of about 3 feet), and another one between the skier's center of gravity and the ankle, again about three feet.

When this type of accident occurs, the skier catches the outside edge of the downhill ski or the inside edge of the other in soft snow and it buries itself. The momentum tends to carry the body downhill in its established track, but the ski tip is fast and won't move; as a result, the ski which is free crosses over and causes the skier to fall, while turning, on his fixed leg. The torque developed in the tibia is great, and results in a spiral fracture. The upper end of the fibula carries away as well, and an accompanying injury to the soft part about the knee is often seen.

In some recent observations, which as yet are incomplete, it appears that the distance of the fracture from the ankle may be dependent upon the speed. The slower the person is going, the lower on the tibia is the break. Certainly, from my own observation, fractures sustained at high speeds occur in the middle third or higher. When the speed is not great enough to produce a fracture, injuries to the knee occur. As would be expected, these injuries are usually tears of the collateral ligaments with an occasional torn meniscus. A great number of these injuries occur each year, many of which are not reported to the Ski Patrol, and hence are not included in the annual accident report.

It should be noted here that the human leg has a pair of built-in "shear pins" in the malleoli. In everyday life, when we wear low shoes, etc., and the leg is subjected to an excessive torque, one or both malleoli will often fracture before the tibia, much as a propeller in an outboard motor will shear its pin when an obstruction is hit, rather than break the drive shaft. In skiing, however, the boot tends

to cancel this natural safety device, and the fall then it transmitted directly to the tibia.

Before concluding, a word should be said about the National Ski Patrol which has done an excellent job of reducing the annual rate of injury in spite of an estimated fivefold increase in the number of skiers in the past ten years. The members of the Patrol are all skiers who have taken the advanced first aid course given by the Red Cross, and then a further course in the handling and moving of the injured under unusual conditions of weather, etc. The Patrol men are the ones who see all of these skiing accidents first, and they are to be complimented on their skillful handling of the victims. I am sure that the average Ski Patrol man sees more fresh fractures than do many surgeons and orthopedists. (Incidentally, here is a source of well trained aid-men for hospital disaster programs which is, as yet, untouched.)

Finally, even though the topic of this paper has been limited to injuries incurred in downhill skiing, a brief review of the recent accident statistics, which includes those from all phases of the sport, is presented. These are compiled mostly from the National Ski Patrol reports and are incomplete since many areas do not have patrols. It is generally estimated that at least as many injuries occur again as are reported. There were approximately 3,500,000 skiers in the United States last year, and each one was thought to have skied twelve days, making a figure of 42,000,000 ski-man days. The reported accident rate was 2.7 per 1,000 ski-man days in patrolled areas; hence, the figure mentioned earlier of 110,000 injuries. It is believed that the accident rate is considerably higher, maybe as many as five per 1,000 ski-man days, in non-patrolled areas.

The age distribution is interesting in that 83 per cent of the injuries occurred in people under thirty years of age, in spite of the fact that it is estimated that more than 30 per cent of the skiing population is over thirty years of age.

About 50 per cent of the accidents occurred in those who have been skiing one year or less. Also, over 50 per cent of the victims were using rented or borrowed equipment of one sort or another.

The anatomical distribution of the injuries was as follows: lower limbs, 79.4 per cent; ankle, 44.4 per cent; knee, 19.2 per cent; leg, 15.8 per cent; face, 5.6 per cent; shoulder, 4.8 per cent; hand and wrist, 2.6 per cent; and all other, 7.6 per cent.

The types of injuries were: sprains, 45.8 per cent; fractures, 29.1 per cent; wounds, 12.7 per cent; dislocations, 8.1 per cent; and other, 4.2 per cent.

From these figures it is estimated that there were about 2,500 fractures of the leg resulting from skiing last season; this figure is low and is subject to at least a 50 per cent error. Of these, there must have been between 300 and 400 spiral fractures of tibias which were the result of falls while skiing downhill.

SUMMARY

I have tried to go over briefly the factors which are present when an injury takes place while skiing. In an effort to help the attending surgeon in his handling of these injured, the equipment, clothing, psychological factors and the ballistics have been mentioned. The pertinent accident statistics, which are sketchy to begin with, are summarized, and we must conclude that: (1) The injuries which occur at high speeds are the serious ones, that is, the spiral fractures of the shafts of the long bones, etc. (2) Skiing accidents occur in the younger age group (sixteen to twenty-eight years of age) at a statistically higher rate than in the older age groups. (3) As would be expected, most occur in those who have skied less than one year and/or who have not had professional instruction.

Finally, it is obvious that skiing is on the increase, and its popularity will undoubtedly continue. We must accept an inevitable minimum of serious accidents among good skiers. If one is going to ski, he should use good equipment, receive professional instruction, and not ski beyond his ability; if so, he stands a reasonable chance of enjoying himself without being hurt.

SYMPOSIUM ON THE IMPARTIAL MEDICAL TESTIMONY PLAN

Impartial Medical Testimony

DAVID W. PECK, LL.B., *New York, New York*

I SPEAK as a lawyer to doctors of a common professional problem—the presentation of medical testimony in court. I should perhaps at the outset make my credentials clear. I am not a specialist in the field of trauma or personal injury litigation. My observations and experience in this area have been as a judge and as one responsible for court administration in a large city.

Seventy-five per cent of the cases in the courts of this country are personal injury cases. Half the time spent in the trial of these cases is spent on the medical inquiry, the nature and extent of the injuries. The medical incidents are thus intimately involved with the congestion and delay which characterize the operation of the courts in all large cities. To the extent that the medical inquiry can be compacted or eliminated from contest in the trial course, trial time can be saved and congestion and delay relieved.

Judges have an equal or greater concern about the rightness of the result reached by verdict after the trial has run its course. Twelve laymen in a box can perhaps tell as well as is humanly possible who is telling the truth and who is lying about how an accident happened; but when it comes to telling which doctors are competent, honest and trustworthy and to resolving disputes of diagnosis and prognosis, a jury is at sea and more apt to be confused than enlightened by conflicting medical opinion.

Honest conflicts of competent medical opinion cannot be eliminated. If such conflicts actually exist in a case, it is probably necessary to let a jury have the last word, although that is neither a scientific nor a satisfactory way of settling the dispute. However, if the conflicts are simulated and staged, and thus multiplied, the incidents and likelihood of error are increased as is the burden on court and jury.

Unfortunately, under prevailing methods of presenting medical proof the court inquiry is not an objective or scientific search for truth but a contest between contending doctors as well as contending lawyers. The doctors are cast in the role of partisans and the lawyers are tempted to look for good testifiers rather than good doctors. The tendency of the doctors is to maximize or minimize injuries in accordance with the interest of the side retaining them, and a premium is placed on personality and patter rather than on competency and integrity. The evil is compounded by the best doctors eschewing a court role and leaving the arena to those whose sensibilities are not so nice.

At best, the method of presenting medical evidence solely through partisan experts is unsatisfactory. At worst, it nurtures incompetency and dishonesty, even corruption. An analysis of the medical evidence in cases in the Supreme Court of New York County, made by the medical consultant to a committee of judges, doctors and lawyers studying court conditions in New York City, revealed that in a quarter of the cases there were gross errors in the reading of x-ray films and that in over a quarter of the cases essential tests to warrant a diagnosis were not made. A recent inquiry revealed the large scale operations of two lawyers of no legal acumen but considerable business cunning, who managed to handle 1,000 cases a year referred to them by insurance

brokers and auto repairmen, blowing up simple property damage cases into alleged personal injury cases by sending their clients, who had not consulted doctors on their own, to doctors of the lawyers' choosing and complicity.

Of course such failings and excesses are not typical of any sizable proportion of either profession, but both professions are tarred by the miscreants and justice is impeded and impaired by the abuses. Of course, also, a closer control should be exercised by the professions over their members and disciplinary authority exercised with greater diligence. But that is not a complete or sufficient answer. A system which allows and encourages the faults and miscarriages so prevalent and inherent in its operation calls for change or at least some built-in corrective or control.

I acknowledge and assert that the responsibility for correction is primarily upon the judges and lawyers; but because doctors also have a stake and a professional and civic responsibility in the matter, I am moved to speak here about what judges, doctors and lawyers have done cooperatively and constructively in one place, and suggest what they may appropriately and effectively do in other centers.

The premise from which we may start is that, while the parties to a lawsuit are entitled to have their own medical advisors and to call them to the witness stand, the court should not be limited or confined by the partisan process of producing evidence but should be able to find and produce medical evidence of the highest authority and unquestioned integrity. Objective truth should be sought from a source which carries the best guarantee of trustworthiness.

It was with these thoughts in mind, five years ago, that the Justices of the Supreme Court of New York County sought a source of reliable expert opinion in personal injury cases. Consultations were had with the leaders of the medical societies and heads of the bar associations in the community, and there was a joint undertaking of the judges and of the two professions to establish a panel of independent experts of the highest standing who would be available to respond to a call from the court for truly expert and objective medical findings on conflicting medical claims. The stated requirement for panel membership was that the doctors should be top authorities in their branches of medicine and men who were not previously identified particularly with the plaintiff's or defendant's side of personal injury litigation. The responsibility of selecting the members of the panel was delegated to a joint committee of the New York Academy of Medicine and the New York County Medical Society.

The procedure employed is simple and best calculated to make most effective use of the panel, with the objective of establishing the medical facts and settling the case without the necessity for a full dress trial. A pre-trial conference is held between a judge and counsel for the parties when the case is instituted. The judge thus ascertains at the outset what the issues are and whether there is a substantial dispute about medical claims, warranting a reference of the case to a member of the panel. It is not the desire of the court to use the panel in all or even most cases. Rather the purpose is to confine its use to those cases in which there is a substantial divergence of medical opinion between the parties.

In those cases a reference to a member of the panel in the required specialty is made, and his report after examination of the plaintiff is submitted to the court and supplied to all counsel. An adjourned pre-trial conference is then held in which the case is discussed in the light of the report of the independent expert. As might be imagined, the medical controversy is usually settled on the basis of the report of the independent expert; and if the dispute as to injury is the stumbling block to a settlement, the case is usually settled forthwith.

The court rule under which the panel was established provides that the independent expert may be called as a witness at the trial by any party or by the court. His testimony is thus made available to court and jury in those cases which cannot be settled and must be tried.

The most tangible result of the use of impartial medical testimony, which can be statistically expressed, is the settlement experience. Equally or more important, the judges and lawyers concerned with the cases in which the panel was used are satisfied that the dispositions made were more in accord with right and justice than would have been likely had the cases gone to trial with only partisan medical testimony produced. And in the cases which went to trial, the judges certainly, and it is believed the lawyers generally, found that

the impartial experts contributed significantly and soundly to the adjudication.

The fees of the impartial experts in New York are in all cases and phases paid from court funds.

A similar plan, employing experts similarly selected but with the fees paid by the parties either by agreement, assessment of costs or direction of the court, has been in operation in Baltimore for several years.

The Section of Judicial Administration of the American Bar Association, after studying the operation of the New York and Baltimore plans, reported that:

"We are satisfied from our observations of the New York and Baltimore experience that the introduction of impartial medical experts of the highest standing into those cases where the parties are in dispute as to the medical facts has the following wholesome and beneficial results: (1) It improves the process of finding the medical facts, vastly increasing the likelihood of reaching the right result. (2) It serves to relieve court congestion by bringing about the settlement of many cases which would otherwise have to be tried and which by their nature would entail lengthy trials. (3) It has a prophylactic effect upon the formulation and presentation of medical testimony in court. (4) The modest cost involved in the payment of independent experts is a positive economy in effecting a large saving in court operations."

The plan and procedure for establishing and employing an independent medical panel may readily be adopted in any community where there is a volume of personal injury litigation in the courts, and where there is a sufficient number of qualified doctors available to constitute a panel.

The first and principal essential of a successful panel program is the selection of experts of the highest qualifications. Such doctors would eschew the role of a partisan and would ordinarily refuse to appear in litigation. They are almost invariably willing, however, to respond to a call from the court as a public and professional duty. It is not difficult, therefore, to recruit a panel, but it is essential that the selection be made by professional bodies on the basis of professional qualifications.

One would think, with the example of the successful Baltimore and New York experiences with impartial medical testimony, that similar programs would be established with alacrity in other centers. But the inertia of judges, the indifference of lawyers, indeed the hostility of some, and the complacency of doctors have been a brake, if not a block, on establishing impartial panels elsewhere. The federal court in Pittsburgh has adopted the procedure and Cleveland is talking about it, but the movement has not gained momentum.

What is needed is more missionary work and cooperative action between judges, doctors and lawyers. Some judges are sparking the movement, but not enough, and the professional bodies in the cities concerned have not taken an adequate interest.

I know that the New York panel and procedure, of which Dr. Craig, Director of the New York Academy of Medicine, was the chief architect, is sound and that it works successfully in every respect. I venture to hope that this Association, of high standing and large influence in the ranks of medicine, will exert some timely leadership in forging a proper link between medicine and the administration of justice.

The Impartial Medical Testimony Project

HOWARD REID CRAIG, M.D., *New York, New York*

THE material which I propose to lay before you has been presented previously before meetings and conferences of Bar Associations and judges, but to my knowledge this is the first time that Judge Peck or I have described the Impartial Medical Testimony Project to a purely medical group and, specifically, physicians engaged in the study and treatment of trauma.

Judge Peck has described the conditions which led to the initiation of the plan, how it came to be, how it operates and its record, together with his own reflections regarding its effectiveness as seen through the eyes of a sitting Justice and a court administrator. I propose to discuss the plan solely from the standpoint of the medical profession as seen through the eyes of one who practiced and taught medicine for twenty-five years and who for twelve years has occupied a medical administrative position.

Inasmuch as one of the vital factors in the success of such a plan is the method of selection and the character of the members of the expert panels, I will devote some time to this important phase of the project.

After informal discussions with various segments of the medical and legal professions, it was deemed wise to set up a joint conference committee made up of the senior officers of The New York Academy of Medicine and the Medical Society of the County of New York. The latter is the local component of the American Medical Association. The New York Academy of Medicine is an independent, endowed institution devoted to lay and medical education, to public health and to the maintenance of a public medical library which with the exception of the National Medical Library in Washington is the largest medical library in the Western hemisphere.

This joint committee set up for itself, within the framework of the project as planned, four very general objectives: (1) the reconciliation of conflicting medical testimony; (2) the general improvement of medical testimony; (3) the attainment of more equable settlements through better medical testimony; (4) the acceleration, with the help of the best medical testimony, of fair settlements. The membership of this joint committee, elected officers of the two organizations, represented a wide variety of institutions and interests and was therefore not open to the criticism of overselectiveness in designating members of the expert panels. At the outset the committee agreed that habitual medical witnesses, that is, physicians appearing constantly in court as expert witnesses for one adversary or another, should be excluded from the panels. Further, it was thought that physicians closely connected with organizations continually involved in personal injury litigation should not be included in the panel rosters. Conversely, it was thought that in order to give these panels weight and authority as well as a position of neutrality free from any bias, their members should be drawn from physicians of professorial rank in the medical colleges or equivalent standing in accredited hospitals. In consultation with the Justices of the Supreme Court the approximate proportions of medical specialists in different categories were set. The committee then studied the list of eligible names. It might be well to point out that the committee had a large pool from which to draw. There are approximately 17,000 physicians in New York City, including 7,000 in the borough of Manhattan, that is, New York County. There are 168 accredited municipal or voluntary hospitals, excluding the proprietary hospitals and the seven accredited approved medical schools.

Invitations were sent out to approximately 100 physicians to serve on the panels. The letter of invitation read as follows:

"A Joint Conference Committee of The New York Academy of Medicine and the Medical Society of the County of New York has undertaken the co-sponsorship of an experimental plan to accelerate and improve the settlement of personal liability cases appearing before the Supreme Court of the State of New York, First District. Additional sponsorship is provided by the Supreme Court, the Association of the Bar, and the New York County Lawyers Association.

"The rationale and substance of the plan is as follows: it has been found possible to settle many of these cases in pre-trial conferences, but conflicting medical testimony has often confused the issues, not only in the minds of the conference judges, but also in those of trial judges and juries. It is proposed that there be set up several panels of physicians engaged in various fields of medical practice, men of the highest professional competence who are neither habitual witnesses nor associated with agencies involved in such cases. These physicians are only to be called upon when there is reasonable doubt as to medical testimony for the plaintiff or defendant and they will be called for by the judges in regular rotation. When called upon, the judge will refer the patient to the physician's office by appointment. The physician will examine the patient and render a report to the judge, copies of the report to be made available to the contending parties. In other words, the physician is acting as a friend to the court. It is anticipated that a great majority of these cases may be settled at this point. In a limited number, however, they may go on to trial; in which case the panel physician may have to appear, again as an authority and friend of the court without regard for plaintiff or defendant.

"Because of the professional standing of the panel physicians, no set schedule of remuneration for these medical services is to be set up. It is expected that each man will render his regular, reasonable bill for his services, realizing that there is a distinct element of public service in his cooperation. After approval by the judge, these bills will be paid by an office set up for the purpose in the Supreme Court building.

"This plan is an earnest effort on the part of the bench, bar and medicine to accelerate the disposition of these liability cases, mete out better justice and wipe out the intolerable medico-legal confusion which has characterized our courts for too many years. With bench, bar and medicine minded to cooperate, this can be done.

"I have been authorized by the Joint Conference Committee of the Academy and the County Medical Society to invite you to serve as one of the physicians on the panel dealing with —. The Committee earnestly hopes that under the conditions set forth above, you can see your way clear to help the medical profession perform this important public service.

"Would you be good enough to communicate with me as early as possible by letter or telephone here at the Academy, giving me your reaction to this proposal."

The response to these letters was most gratifying. In order to show the attitude of the physicians toward this plan, may I offer a few excerpts from letters accepting positions on the panels:

"Although I dislike very much to be involved in court cases, I feel that it is a duty to attempt to improve the handling of liability cases for the Supreme Court, and I accept your invitation to serve on the panel for orthopedic specialists for that purpose."

"I have seldom received a letter which pleases me more than yours of December 30th. For 20 years, I have been trying my best to improve the character of medical testimony in liability cases. The plan which your letter suggests has my unqualified approval, and I am delighted to serve on the panel of physicians. I feel that if these problems can be solved without recourse to court trial, much should be gained."

"Although I dislike very much the wrangle of court cases, I feel that it is my duty as a public service to accept the invitation to serve as one of the physicians on the panel of genito-urinary surgery."

"I was very much interested in your letter and feel this is a very important step in an attempt to get more real scientific information and more justice in these cases. Many of them certainly are or have been cases of legalized blackmail. While I am terribly busy and do not like to take on more obligations than I am able to fulfill satisfactorily, I consider it a great honor and duty to help in any program of this kind. I shall be glad to serve on this panel and will do all I can to help in the aims of this plan."

"I dislike intensely these contacts with our legal confreres, but it seems to me that our private feelings, from time to time, have to be subordinated to the public good. I shall, therefore, accept the appointment and promise to help you as much as I can."

"In reply to your letter of December 29th, it will give me great pleasure to participate in your program to improve the settlement of personal liability cases. I have made it a rule not to take litigation cases, but I believe that the purposes of this experiment are so worthwhile it should receive all the encouragement possible."

Only three individuals declined, and they gave personal reasons for their inability to serve. The general tenor of the affirmative replies was to the effect that although the physicians disliked intensely and avoided, if possible, appearance in court, a sense of public duty and public service prompted their acceptance of the responsibility.

The distribution of the specialists by categories may be of interest: general surgery, seven; plastic surgery, four; ophthalmology, three; dermatology, three; neurosurgery, ten; psychiatry, eight; roentgenology, ten; obstetrics and gynecology, five; genitourinary surgery, four; orthopedics, fifteen; internal medicine, five; cardiovascular disease, five; tuberculosis, four; neurology, six; neuropsychiatry, one; otolaryngology, four; endocrinology, two; malignancy and trauma, one. Thus we have a total of ninety-seven panelists to which were later added twenty-eight physicians from the borough of Bronx, chosen by that County Medical Society, thus making a total of 125 panel members on call for service.

Judge Peck has described the mechanics of calling for the services of the panelists. However, I believe it worth while to read the directive and information which is sent to each physician panel member when a case is referred to him:

INFORMATION FOR PANEL SPECIALISTS

"1. You are in complete control of the conduct of the examination. Any attorneys who may be in attendance are there for your convenience and to assist you, if you wish them to do so. You may, if you desire, exclude them from the room in which you conduct the actual physical examination of the litigant.

"2. This office is ready to accommodate itself to your convenience as to time. If at any time you are too busy to handle an examination for us, please do not hesitate to say so and we'll pass you by on the rotation of the panel.

"3. It is the intention of this office to see that you have all the available medical background material on each case before the examination takes place. At the bottom of the letter which is sent to you confirming the appointment agreed upon over the telephone, there appears a statement that counsel in the case have been instructed to submit to you their own medical reports, etc., by a certain date. This date is usually a few days before the time of the examination. This is intended to give you time to go over the background material in advance of the appearance of the 'patient.' Occasionally the attorneys have difficulty in providing this material in time, in spite of the instructions of this office. It is suggested that if these records are not received by you by the day before the examination date, you call this office and an attempt will be made to correct the situation. With regard to the hospital charts, x-rays, test reports, etc., taken in the hospital, we have been able to establish a procedure whereby the attorney subpoenas the hospital's records for delivery directly to your office. You keep the records in your possession until you have no further use for them. Then, if you call the record room of the hospital involved, they will have a messenger call for the record.

"4. In view of the fact that in many cases the names of the doctors who have treated or examined the litigant are confidential, it is advisable, wherever possible, to avoid mentioning the names of the doctors whose reports have been submitted to you by counsel. This applies particularly to the written report made by you, a copy of which is supplied to all parties in the case. If you find it unavoidable to omit these names in your written report, please consult this office before your report is typed.

"5. You are authorized to order x-rays, EEKs, EEGs, or other essential tests required to assist you in your examination. These should be made at the same reasonable rates and on the same basis as you use to set your fees in the cases referred to you by this office. It would be convenient for these charges made by outside persons to be billed to you directly and for you to include that charge as an item in your bill to us. This system is suggested, provided it doesn't unduly interfere with your normal procedure. If it does, do it your way.

"6. Regarding your bills, one copy of the bill, sent with your reports, is sufficient. If your bill has not been paid within three months after its date, it would be appreciated if you would have your secretary call this office. It may possibly have been overlooked and this reminder would be welcomed.

"7. The panel specialist should retain in his file any x-ray plates, EEGs, EEKs and other laboratory reports ordered by him to assist in formulating his opinion. (This does not include original hospital records.) In the first instance, the

court is mainly interested in the panel specialist's interpretation and conclusions on these x-ray plates, etc. Secondly, in the future, if the panel specialist should be called upon to testify in court, he will have readily accessible, in his office, the complete file in the case.

"8. We have a deadline to meet in each case, the date upon which the Court has arranged the conference following your report. However, wherever possible, we will forego our deadline for your convenience, at your request for more time. Please call this office and if possible, advise when we can expect your report.

"9. All communications regarding your availability for testifying in a case in which you have made a report should be had through this office, rather than directly with the attorneys. We are in a better position to make the most convenient arrangements as to your time. If you are requested by any attorney to testify in any of the cases handled by this office, please advise the attorney that this office will have to handle all communications. . . . "

I have dealt in detail with the selection of the panel members and the responsibilities of the physicians involved because, although the over-all principle on which the project was based may be sound, its success and effectiveness depend to a great degree first on the character, competence and reputation of the panel physicians, and second, on meticulous attention to detail in the administration of the system. I have mindfully omitted reference to the responsibility of judges and lawyers in effecting the success of the plan inasmuch as I am discussing those aspects which touch on the medical profession.

The basic function of the panel physician as a recognized expert is to review the case in its entirety in the light of his own knowledge, training and experience, and having done so to transmit his opinion to the court. It is of interest that of 100 cases reviewed by the medical consultant to the study there were twenty-four cases in which by the experts' opinions there were errors in x-ray technique or interpretation. It is of further interest that of the same 100 cases there were twenty-seven cases in which a diagnosis of fracture of the skull or cerebral concussion or both was made but no spinal puncture was carried out to confirm or deny the diagnosis. These two examples alone call for more expert x-ray diagnosis and greater use of lumbar punctures and electroencephalography. Particularly is this true in cases of head injuries and fractures.

To those of us in medicine who have been involved in this project, there is no doubt that the plan has materially increased the possibility of finding true medical facts in litigated cases; that it has a prophylactic effect on the character and presentation of medical testimony whether in pre-trial conference or in court, and that it has pointed the way to better diagnosis in cases of trauma.

The system has been eminently successful in the stage of pre-trial conference, helping to stop litigation at that point. When it comes to court actions, it is possible that some minor modifications may be necessary, but these will not detract from the soundness of the basic principle of unbiased, neutral medical consultation to the court.

In order to ascertain the reactions of panel physicians who had appeared in court, a questionnaire was distributed. On the whole the responses were decidedly favorable to the plan. I will quote just two comments from these replies. Comment A: "From my experience in the courts, I am convinced that the doctor should give testimony, not for one side or the other, but with the same degree of impartiality that the judge is supposed to show. You may, therefore, count on my enthusiastic support in trying to reform the old system." Comment B: "The all-important essential for the success of the plan is the proper selection of the specialist. He must have not only the requisite technical and clinical knowledge, but also a judicial type of mind. As a rule, the older and more experienced physicians are more likely to meet up with these standards."

How applicable is this system of impartial medical testimony to communities other than New York with its heterogeneous population and its heterogeneous medical and legal groups? Granting that the need—in terms of court congestion, of confusing medical testimony, of questionable judgments and high court costs—is a real one, there is no good reason why this concept of impartial medical testimony should not be practicable in most communities, possibly with some modifications to meet local conditions. However, appended to that statement are three provisos. First, the judiciary must recognize such a need and have the desire to correct it. Second, the medical profession

must see in the plan an opportunity for real public service. Finally, the legal profession must see in the plan a step toward fairer judgments, settlements more quickly achieved and a contribution to the public good. Distilled to its real essence, the plan involves an interprofessional cooperation which when once achieved—and this experiment has proved that it can be achieved—will redound to the credit of the law and medicine, and increase public trust in the administration of justice.

The Impartial Panel of Medical Examiners

HARRISON L. MCLAUGHLIN, M.D., *New York, New York*

WHEN first invited to become a member of the Impartial Panel which Judge Peck and Doctor Craig have described, I found myself in somewhat of a quandary, for my immediate reactions were quite contradictory. I did not want to have anything to do with it and yet I knew I should. I wanted no part of anything that might entail an appearance in court as a medical witness. But here was organized medicine and the law collaborating in an effort to clean up a mess for which neither was entirely blameless. And so, with more than a few misgivings, but because this eminently worthy project was sponsored by such stable and responsible bodies, my acceptance was inevitable.

As I recall my misgivings, which at the time seemed very well founded, it now occurs to me that they were really nothing more than the reflection of two emotions—anxiety that I might not acquit myself creditably amid the complexities of legal and court procedures about which I knew nothing, and unpleasant memories of real or fancied personal affronts and inconveniences which had attended my previous unavoidable entanglements in court.

Prolonged association with a trauma service had subjected me to an equally long and liberal education in the ways, wiles and importunities of lawyers who wished to buy my services as a witness, and in the blandishments of litigating patients who desired an additional advocate. All paid lip service to the truth. None ever asked outright for testimony that was anything but the truth, but few seemed interested in the whole truth—only that portion of the truth which would be self-serving.

I recalled the time and trouble entailed in building around my usual daily haunts an impenetrable defense against these onslaughts. I had visions of a disintegration of the personal ivory tower in which I had enjoyed such a splendid isolationism from matters legal. I had memories of the inconveniences and of the actual or potential neglect of medical responsibilities necessitated by my few previous appearances as a medical witness, and of the times I had been enjoined to appear as a witness and had waited around interminably in some courtroom, only to be dismissed finally after a wasted day with the offhand advice that the case had been settled out of court. There were bitter memories of the distaste associated with certain techniques of cross examination—techniques which, by innuendo, questioned my competence, cast suspicion upon my motives and in general promoted an acute (if temporary) collapse of my ego.

Above all, there was an abhorrence for participation in any situation which might permit even the strangers in a courtroom to place me in the same category as some of the professional medical witnesses I had had the opportunity to see and hear in action. For who is there in any court to tell the judge and jury which medical witness is, and which is not, exploiting his ignorance or prostituting his profession?

And so, with these misgivings in the background, I became a member of the Impartial Panel of Medical Examiners, and awaited my first assignment with both curiosity and trepidation. It was not long in coming, and the pattern of its implementation (which I shall outline) has remained constant throughout the many subsequent examinations which have been delegated to me.

I received a call from a man who introduced himself as a representative of the Medical Records Office of the Supreme Court. He was not importunate. He called sufficiently in advance so that a date for the examination he wished me to make would be convenient for all parties concerned. He was (and is to this day) much more considerate and understanding than the average doctor who refers a patient for consultation.

Informally, when necessary, he may apprise

me of the particular discrepancies in the medical evidence available which necessitate an impartial examination, or of some specific medical point upon which an impartial opinion is desired. He makes certain that prior to, or coincidently with the examination, both parties to the action provide the examiner with all medical data in their possession (including x-ray films, photostatic copies of hospital charts, doctors' reports, etc.). Almost invariably the plaintiff is escorted by counsel to the impartial examination. However, contrary to what experience might lead one to expect under such circumstances, none of these counsellors has ever been anything but helpful, considerate and respectful, and it has been a source of some gratification to realize how many plaintiffs' lawyers seem as genuinely interested in their clients' physical and emotional welfare as in the potentialities of their legal position. Consequently these examinations have been carried out in an atmosphere that has been wholesome, pleasant and devoid of inconvenience or suspicion.

A report is submitted, similar to that which one would make to a referring physician, but also incorporating an adjudication or explanation of real or apparent discrepancies in the medical data reviewed. Whenever possible a firm answer to any specific medical question that has been raised is included. After reviewing this report, the presiding judge may (upon occasion) call the examiner and informally question him further in order to clarify specific points which bear upon the decision he must make and which his layman's mind has been unable to resolve.

Having accepted this assignment as a duty of good medical citizenship, it was a pleasant surprise when the same man who arranged the appointments also requested that a bill corresponding to regular consultation fees be submitted with each report. In a committee report on the activities of this project (published in book form by the Macmillan Company and entitled "Impartial Medical Testimony") it is stated: "Fees charged by impartial experts for making examinations and reports (not testifying) have ranged from a low of $25 to a high of $200. The average has been about $55 per examination." It is clear from this that the efforts of the impartial examiners have not been entirely labors of love.

Finally there came the day when the man from the Medical Records Office called and apologetically informed me that my presence was required in court to substantiate a report which I had made. Although this has happened only once in my six years of association with the project, it was the day I had feared. But what a difference there was between this and previous court experiences. There was no subpoena. I was advised of the dates and probable duration of the trial, and invited to designate the day and hour at which it would be least inconvenient for me to attend. Upon my arrival in court at the appointed time the proceedings were interrupted at the first opportunity and my testimony taken without delay. The examination and cross examination were sharp and stimulating, but clean and friendly. I was, indeed, treated as a friend of the court, and as such the impact of my testimony was apparent, even to me.

This raises the only point about which I have any personal reservations concerning the propriety of impartial medical testimony. Medical opinion is, of necessity, predicated upon variable proportions of scientific fact, accepted theory, common sense and what our legal colleagues disdain as speculation. There are, and will remain, great voids in medical knowledge concerning which the most authoritative of opinions must be based upon presently accepted theory and speculation, and about which one opinion, whether partisan or impartial, may be fundamentally as valid as another. This places a great, and possibly an unwarranted, responsibility upon the court to "separate the wheat from the chaff," and as great a responsibility upon the impartial examiners to refrain from any exploitation of their status as "friends of the court."

Judge Peck has described the effectiveness of this program in facilitating and accelerating the settlement of claims and the healthy influence it has had on a reduction in the backlog of personal injury suits pending trial. The dilettante physician might retort: "These things are benefits which accrue to the legal profession and have no bearing upon medical problems or treatment." However, this is not true. Was it not Plato who said 2,000 years ago: "This is the greatest error in the treatment of human sickness—that there are physicians for the body, and physicians for the soul, and yet the two are one and indivisible"?

Only the surgeon with his head buried in the

sand will fail to recognize that litigation is a most common and potent source of chronic emotional stress which delays and, indeed not infrequently, precludes complete recovery from an injury and may produce a chronic physical and emotional invalid. It is not necessary to dwell upon the harmful and mischievous influences against recovery so very often exerted by lawyers and litigation. It is enough to say that they can be prevented or palliated by any surgeon who is interested in his patient as a person as well as a problem if he will only take the time and trouble to do so. Neither is it necessary to emphasize the therapeutic benefits inherent in a speedy termination of these intangible adverse influences.

Therefore I can do no less than congratulate Judge Peck and Dr. Craig and their colleagues upon the development of a program which, as I have observed it, not only benefits medicine and law but also the effects of which constitute good sound medical treatment.

I submit that it would not be amiss for national associations of medicine and the law to collaborate toward a geographical extension of this or some similar plan.

I commend this thought to The American Association for the Surgery of Trauma, along with the information that 80 per cent of all the cases in trial courts of the United States are suits for the recovery of damages consequent to personal injuries.

DISCUSSION OF THE SYMPOSIUM ON THE IMPARTIAL MEDICAL TESTIMONY PLAN

MODERATOR WILLIAM E. MISHLER (Cleveland, Ohio): It was thought that this Symposium would be timely because in the largest percentage of cases of litigation today medical reports or testimony is required in these cases. Hence the role of the physician in the administration of justice is of major importance. The adversary system of the courts has taken advantage of the differences that exist in medicine so that all too often one cannot believe that two doctors are testifying about the same patient. This has not brought honor and respect to the medical profession. However, medicine does recognize that objectivity and impartiality are the essence of good medical testimony. Members of the legal profession are equally aware of this fact.

The New York Impartial Medical Testimony project has been enlarged upon by Judge Peck. The American Bar Association reports favorably on the use of impartial medical experts and has stated there have been these effects:

"It improves the process of finding the medical facts, vastly increasing the likelihood of reaching the right result.

"Serves to relieve court congestion by bringing about the settlement of many cases which would otherwise have to be tried and which by their nature would entail lengthy trials.

"It has a prophylactic effect upon the formulation and presentation of medical testimony in court.

"The modest cost involved in the payment of independent experts is a positive economy in effecting a large saving in court operations."

Judge Peck and Dr. McLaughlin are very anxious to answer any and all questions on this plan.

RICHARD HELLER (Chicago, Ill.): As Chief Medical Officer for one of the larger insurance companies operating in Chicago, I have been very much interested in this problem. We have a number of physicians in town who are falsifying medical claims. We have tried to stimulate the Bar Association and the people involved in this field to develop such a program as has been outlined here. It has been virtually impossible to get anywhere. I would like to ask Judge Peck how in the world he got this program into operation, and how he got past the medical group living off improper medical testimony and the attorneys involved in this type of livelihood.

JUDGE DAVID W. PECK: Well, Dr. Heller, such a project is not too easy. A desirable place to begin certainly is by getting the judges interested, and I think they are getting interested.

I was in Chicago approximately six months ago talking to the judges of the Federal Court about this program to see if they would be interested. I really do not know whether they were or not, but it was picked up by the Federal judges in Philadelphia and I think the judges in Chicago are beginning to consider it.

As far as the Bar is concerned, I might tell you this, which you probably know. The major public relations operation of the Bar in the city of Chicago and the state of Illinois for the last three or four years has been trying to reorganize the court system in this state which is not very good, and they have a plan which has passed the legislature and which is going to come up for vote this November. If that plan is adopted, I think the Bar members of this city and state will believe that they have accomplished something important and will be sufficiently encouraged to move forward, and should then be in a frame of mind to pick up this project which has now been talked about enough so that lawyers and judges generally are familiar with it. However, I think it is quite essential that the judges receive some stimulus from the medical profession, and I would say, to come right to grips

with your question, that you should get the medical society or societies in your county interested in this program and get them to approach the leaders of the Bar (not the specialists in this particular field of litigation). If the leaders of the Bar Associations, the Court and the medical societies—it does not have to be a large group—get together and decide that they are going to initiate this project, they can do it.

MODERATOR MISHLER: There is a question as to what papers or books have been published on the subject. Dr. McLaughlin mentioned there is a book entitled "Impartial Medical Testimony," published by the Macmillan Company, which covers the establishment and results of the Impartial Medical Testimony Plan in New York.

JUDGE PECK: I might add that the book is a complete report on the New York experiment. We had both a director who kept a record of all the proceedings and a medical consultant to whom Dr. McLaughlin and I have referred, Dr. Irving Wright of New York City, who made an analysis of all the cases brought to the attention of the panel and case by case gives his notes in this book.

The book is not large but it is very good source material for anyone who would like to get the details on a case by case basis of how the New York experiment has functioned. That was a report over a two-year period of time. This experiment was financed as a pilot project by the Alfred Sloan Foundation and the Ford Motor Company Fund. The fees of the doctors were paid from that fund for two years while we observed how it worked. It is the net result of the satisfactory experiment that we decided to adopt this program as a regular part of our court procedure and as a regular part of the court budget, including all payments to the doctors.

DAVID L. REEVES (Santa Barbara, Calif.): I would like to ask Judge Peck about the contingency fee basis, wondering if it would not be more reasonable to have a fee set of, say, 10 per cent instead of 40 or 50 per cent. I say that because on damage suits when $200,000 has been awarded, the attorney receives somewhere in the nature of $90,000. It seems to me that if the contingency fee basis were regulated at a more reasonable level, perhaps the stimulus for some of these suits would be on a more justifiable basis.

JUDGE PECK: Doctor, I agree with you. The fees in these cases are unconscionable. In New York they have gotten to the point where the regular retainer arrangements in most cases is 50 per cent. I do not think it is as high as that in other parts of the country where it probably runs more closely to a quarter or a third.

I might say that in the court over which I was formerly presiding the justice attempted last year to put in some regulations of contingent fees and to get them reduced. The Bar, the plaintiff specialist bar in this field, challenged the authority of the court to regulate fees in any way, and I must say that they have been successful in their attack through an intermediate court.

The question is going to the highest court in the state of New York. You are too low in your suggestion of 10 per cent, I would say. There is an awful lot of work to be done in these cases. The fees are necessarily paid on a contingency basis. Of course, it would be desirable if they were not on this type basis at all, if that were possible. Incidentally, in England fees are not paid on a contingency basis; it is against professional ethics there to have anything on such a basis, and their law society arranges for the financing from public funds of these cases for indigent plaintiffs and the lawyers are then paid and assured of quite reasonable fees. There is no arrangement in this country of that kind, so of necessity they must be on a contingency basis. What is a fair contingent fee? I would say that certainly 25 per cent is fair. Perhaps in some instances it should be more than that, but in some cases it has risen to very unconscionable degrees, economically, socially and professionally indefensible.

JAMES KEANE STACK (Chicago, Ill.): I have a question for Judge Peck. There is an association called N. A. C. C. A. which means the National Association of Claimants' Compensation Attorneys. One of their prime cases against the impartial panel is the presence in court of a friend of the court, who is known to be a friend of the court to the jury. This Association considers that this is an erosive factor as far as the principle of the jury system is concerned.

JUDGE PECK: On the point you raised, Dr. Stack, that is a very important matter. It is something that I would certainly discuss in this field in any Bar gathering. I had not touched upon it because I did not know if the doctors would be interested in it. Undoubtedly—and Dr. McLaughlin made that clear—the presence of the independent expert under the egis of the court does not quite put a halo around him, but it does give him a standing which inclines the jury to accept what he says. In my mind it has not been bad, but naturally in the mind of the lawyer who has a different view of the case it is bad.

What are the choices in the matter? The choices are either to let the doctor testify with certain instructions and clarifications from the judge or to say because of the risk involved he should not be permitted to testify at all.

Now the judge instructs the jury on just who the doctor is and what he says, so they will know the facts. However, the judge goes on to say that just because the doctor is an independent expert in the court does not mean that the jury is to

accept his word. He has been subject, as Dr. McLaughlin said, to examination and cross examination, and the jury is to determine in his case, as in the case of any witness, whether or not they want to believe him or how much.

Now the answer I think to the N. A. C. C. A. people is simply this. Surely a jury is subject to being impressed by this doctor, but does that mean we must confine ourselves to a procedure in which a jury may not hear anybody except partisan experts? Sitting in their ignorance, dependent as they are on professional guidance in this area, must the rule be that they cannot be exposed to anybody except someone who is hired and paid for by the parties, and that they must not be exposed to anybody who is an impartial expert? The jury has the presumed capacity—indeed, duty and responsibility—of passing upon these medical claims. Are they more likely to be led correctly or astray by having the independent medical expert there or by having him shut out of the courtroom? To my mind, the question dictates a perfectly obvious answer.

Now a word or two more about the N. A. C. C. A. I think they have certain misguided notions. There is a tendency on the part of lawyers who practice in this field, and I must say it exists on the part of attorneys of the defendants as well as the plaintiffs, to regard the court as their preserve in these matters, that they should run the proceedings the way they want to run them, and that the judge and jury are supposed to allow the lawyers to do so.

That does not happen to be my idea or the modern idea of running a courtroom. The judge has certain responsibilities, and it is time to get cases more organized. It undoubtedly to a certain extent does cramp the style of a lawyer to introduce into the courtroom impartial medical testimony. However, let me say that all will have to recognize, on the basis of the record, that this is no one-way street.

In New York County we have had seventy-five trials in which doctors have been called to testify. Of those seventy-five trials the doctor was called by the plaintiff's attorney in thirty-five cases, by the defendant's attorney in thirty-nine cases and by the court itself in one case. If you will delve into the aforementioned book, you will find some very interesting statistics showing how as a result of the independent experts' inquiries and reports the claims and the demands fluctuated up and down. It happened both ways; even in some cases the plaintiff's claim went up substantially after the impartial medical expert reported on the case. He not only sustained the plaintiff's claims fully, but found the injuries were even more substantial than the plaintiff, his doctor and lawyer thought they were.

FRANK MCDOWELL (St. Louis, Mo.): I have been very interested in this plan and our local St. Louis Medical Society has been interested in it for some time. We appointed a committee which met with the committee from our local Bar Association several times. The committee of the Bar Association met the proposal in a rather lukewarm manner. They did not turn it down, nor did they favor it; it just seemed to generate no enthusiasm.

We have talked about contacting the judges in our community. I would appreciate it if Judge Peck could give us a few more hints on just how to go about it. First of all, in our community a great many of the cases go into the Federal as well as the State Circuit Courts. I would like to know if there is anything in the law that would prevent use of this plan in the Federal courts. Whom should we contact? Is there an association of judges? We want to do it with propriety.

JUDGE PECK: Dr. McDowell, I am glad to be able to hit your question right on the head. There is a judge in St. Louis named Ivan Lee Holt. Do you know him?

DR. MCDOWELL: He is my next block neighbor.

JUDGE PECK: I would suggest you contact him and tell him that I advised you to see him. He is very much interested in this problem. I was talking to him about this subject at the American Bar meeting at Los Angeles recently. I think he is ready to take hold of this subject.

There is no reason why this plan should not be used in the Federal, State or County Courts. As I have stated, in the Federal Court in Philadelphia they have already adopted a rule on this, and at the request of Judge Holt, as a matter of fact, made to me in Los Angeles, I have just sent him this rule out of the Federal Court in Philadelphia.

MODERATOR MISHLER: Thank you very much. If there are no more questions, we will call this discussion to a close.